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ELEMENTS

OF THE

ECONOMY OF NATURE,

OR THE

PRINCIPLES OF PHYSICS, CHEMISTRY, AND PHYSIOLOGY:

OUNDED ON THE RECENTLY DISCOVERED PHENOMENA
OF LIGHT, ELECTRO-MAGNETISM, AND
ATOMIC CHEMISTRY.

BY J. G. MACVICAR, A.M.

> Ἄριστα ὦ Τίμαιε.
>
> PLAT. in *Tim.*

AM BLACK, 27. NORTH BRIDGE, EDINBURGH;
ND LONGMAN, REES, ORME, BROWN, & GREEN,
LONDON.

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TO

THE REV. PATRICK MACVICAR, D. D.

DUNDEE.

My Dear Father,

The pleasure with which I am able to dedicate this Volume to you, is the best evidence to me that it is not unworthy of being laid before the Public. For, if my scientific researches had terminated in opinions less sacred and ennobling than those which I learned from you in those years when creation as known to me was made up of home and heaven, as I should have felt that to prefix my Father's name to my Work had been a violence which filial affection could not have excused, so I should have concluded that my philosophical opinions had better remained unknown.

I cannot but fear, however, that the following pages are too pretending to be received by men of fixed opinion, without opposition, even though they were true. It is not therefore as an attempt to honour you, that I beg your acceptance of this Volume; but rather because it cannot be displeasing to you to learn, that, after many years devoted to the observation of phenomena, and to anxious inquiry into causes, the results which I esteem most highly, are but echoes of the voice of paternal affection.

JOHN GIBSON MACVICAR.

"I say then, in short, that, in an opinion, I look upon its being new or ancient, and its being singular or commonly received, as things that are but extrinsic to its being true or false; and as I would never reject a truth for being generally known or received, so will I not conclude an opinion to be a truth for being generally known or received, merely because great numbers have thought it to be so, nor think an opinion erroneous, because it is not yet known to many, or because it opposes a tenet embraced by many. For I am wont to judge of opinions as of coins. I consider much less, in any one that I am to receive, whose inscription it bears, than what metal it is made of. It is indifferent enough to me, whether it was stamped many years or ages since, or came but yesterday from the mint. Nor do I regard through how many or how few hands it has passed for current, provided I know by the touchstone, or any such trial, purposely made, whether or no it be genuine, and does or does not deserve to have been current; for if, upon due proof, it appears to be good, its having been long and by many received for such, will not tempt me to refuse it. But if I find it counterfeit, neither the prince's image or inscription, nor its date (how ancient soever), nor the multitude of hands through which it has passed unsuspected, will engage me to receive it; and one disavowing trial, well made, will much more discredit with me than all those specious things I have named can recommend."—BOYLE.

PREFACE.

The credibility of any scientific theory, considered as a true statement of the mechanism by which phenomena are evolved, can never be established upon an absolute demonstration of its truth, nor otherwise than by a greater or less amount of probable evidence. A hypothesis may be wrought out by demonstration, as is at present commonly done in physics, by the use of the calculus. But the discovery resulting from all such demonstrations is never more precise than this, that such or such a supposition explains a certain number of phenomena. Whether it be an accurate statement of the natural mechanism, by which the phenomena considered are brought to pass, is an inquiry which can never be disposed of otherwise than by canvassing its probability and accumulating evidence. Although a hypothesis may explain all the phenomena to which our knowledge of nature enables us to apply it, we can neither affirm that it is competent to explain all those phenomena which it ought to explain, nor that all other possible suppositions are inadequate to account for those to which our knowledge extends. We have the means of demonstrating that ninety-nine hypotheses are false, but we have not the means of demonstrating that the hundredth is true. A hypothesis, therefore, based solely upon its competency to explain a certain number of phenomena, must still be viewed only as a *possible thing*. Whether it be a *probable thing*, must depend upon its intrinsic verisimilitude, its accordance with what we find to be true by observation of nature generally: for the mind feels that whatever is extravagant and singular, and does not accord with the general harmony of truths, is monstrous, and can scarcely be true; and to disregard such native and aboriginal testimonies of our constitution, is to divorce common sense, and to become sophists instead of philosophers.

The evolution of a hypothesis, therefore, ought to include two eras of mental action: the first a process solely of generalization or *induction of particulars ;* because, if any thing be involved in the phenomena contrary to the hypothesis pretending to be deduced from them, its truth is impossible: the second, a process of analogy or *induction of generals*, in which one general idea, whose truth is inquired into, is compared with other general ideas known to be true, with a view to discover a harmony or discrepance in their features. At the close of the first era, we have discovered that our hypothesis may be true, or that it is absolutely false; at the close of the second we have found, that it falls into a place in the system of nature so well, that we are quite convinced of its being a part of that system, or else we may still feel that, notwithstanding its ability to account for many appearances, it remains so deeply impressed with the hieroglyphics of ingenious ignorance instead of the simple seal of nature, that we cannot receive it as genuine. In modern science (chiefly in consequence of an excessive subdivision of labour in scientific occupation, and the constant use of mathematics in working out hypotheses, which have this peculiarity that they do not demand collateral knowledge of any sort in the mathematician, and, therefore, do not expose him to a feeling of incongruity between his hypothesis and the general tenor of nature), the intrinsic verisimilitude of conjectures as to the causes of phenomena is very little regarded. But, it will certainly be admitted by every one who reflects, that *verisimilitude* is a quality devoid of which a hypothesis can scarcely recommend itself to the belief of any well-informed and intelligent observer of nature.

Such are the principles by which the views contained in the volume now in the reader's hands, pretend to have been detected and tested; and because the author has satisfied himself of their truth, he has not spoken more hesitatingly than the state of his convictions naturally suggested. The reader will perhaps feel offended at the confident manner in which he treats even of things often thought to lie beyond the pale of discovery; but, if the views advanced be found true, this feeling will soon disappear, and if they be not true, there is no good reason why the reader should not be offended from first to last.

As to the manner in which the work has been composed, convenience rather than logical art has been attended to.

Thus, to save space, even the analytical parts of the investigation are usually stated in the synthetic manner. When a general idea is not expressed till after a detail of all the phenomena from which it pretends to be deduced, either a great repetition is required on the part of an author, or double work on the part of the reader; for we never perceive all that we ought to perceive in the narration of a phenomenon, until we have been made acquainted with the hypothesis by which it is to be explained; and if an author does not acquaint us with the object which he has in view in narrating a phenomenon, till he is just closing the discussion which relates to it, we feel that he is abrupt when he closes, or we are necessitated to read the pages over again after his object has been made known to us. As to the absolute amount of evidence on which it rests its claim to belief, of course it can make no difference whether a general idea advanced to explain certain phenomena be stated as the first or last proposition, whether it be placed on the right or left hand, of the phenomena which relate to it.

It is common with modern authors to give the history of the development of their discoveries (including even their unsuccessful experiments) along with the ultimate opinions at which they arrive on any subject. But if the truth of these ultimate opinions be not admitted by the reader, the effect of such a display is so ridiculous, that the author has avoided this hazard. I may merely mention that it first occurred to me, when occupied in examining some phenomena of double refraction, that certainly there was some very attenuated medium between the table on which the spar lay and the window-shutter through which the sunbeam was admitted, not altogether dissimilar to the spar itself, but composed like it of molecules (though very minute and distant), symmetrically related to each other, and having a specific form, over which light was some excitement shot along, as magnetic and electric polarity are in the media which conduct these principles. If so, it was obvious from its optical phenomena, that the medium of light possessed a tessular structure, and that the form of its molecules must be found between the sphere on the one hand and the tetraedron on the other. Now, as their particular shape has neither been revealed nor as yet discovered, there seemed no good reason why any one who had a disposition to occupy himself in such a way, and leisure enough for the inquiry, should not attempt to do the same. A sure way to make such discoveries impossible, is to suppose that they are so, which, if the state of the case be otherwise, is, in point of fact, more presumptuous than to spend many months in fruitless labour.

The highly angular character of the simplest and most exquisitely crystalline bodies, and the very peculiar character of the phenomena of physical optics, which have never been accounted for on the usual supposition that the atoms of light are merely globules, without modifying and complicating the hypothesis till it lose all verisimilitude, induced me, in attempting to detect the fundamental structure of the radiant medium, to turn to the angular extreme of the series. It was obvious that very peculiar phenomena would result from cleaving by reflection, &c. a medium composed of a symmetrical tissue of tetraedrons. The intrinsic verisimilitude of such a hypothesis was also a maximum, for it seemed an idea most congenial to the nature of things, that the most elementary of all media should consist of atoms whose form was the simplest possible. The subject seemed worthy of a serious inquiry, and this I was enabled to conduct without interruption, happening to have by me a set of experiments which I had previously made on the polarization of solids. The result of that inquiry is now brought before the public, in the belief, that if the views advanced as to the structure and economy of nature be true, they will ultimately be received.

The reader will, I fear, discover many errors into which I have fallen in attempting so extensive a survey of creation; but it was better that I should run the hazard of committing particular errors in detail, than that my views should be stinted of evidence, by the fear of that ungenerous criticism which settles upon an author's errors only. If such cases be found, therefore, the generous reader will only substitute his own more accurate knowledge in the place of the error into which I may have fallen, or, striking out my errors, will consider whether the facts remaining be not adequate to demand belief in the system advanced.

As history should be connected with standard works rather than with those which depart from current opinions, no pains have been taken to associate the facts made use of with the names of their discoverers, which indeed, without such an apology, it would have been impossible for me to do in a satisfactory manner, having hitherto usually contented myself with domestic works, and compilations of opinions intead of original papers and monographs, from which only the true character of an author can be learned.

The student of natural and chemical science in this country may, indeed, congratulate himself that all the great branches are cultivated at home with a success which renders him somewhat independent of information derived from a distance. Thus, in Physical Optics, which lie at the very root of natural science, Dr BREWSTER is a host. Mineralogy, which is the second branch of science resulting from the evolution of natural bodies, has received the particular regard of Professor JAMESON, to whom Natural History in Scotland is so deeply indebted, and whose kindness to the Author, in granting every facility to him in the prosecution of his studies, he is happy of this opportunity to acknowledge. Atomic Chemistry, which is the third branch, has nowhere a more gifted advocate than Dr THOMSON. In Zoology including Physiology, which is the fourth and ultimate, we possess Dr FLEMING, a highly gifted naturalist of singular penetration and love of truth: while all, and especially those who propose to make the result of their inquiries public, know what a treasure the science of Scotland possesses in Mr NEILL.

The Author is anxious to mention also, as men to whom he has been most deeply indebted for scientific knowledge, such names as OERSTED and FARADAY—BIOT, ARAGO, HERSCHEL — MOHS and MITSCHERLICH — GAY-LUSSAC BERZELIUS, and PROUT—CHARLES BELL,—CUVIER, &c. &c. &c. But he feels that in such an attempt, his very partial knowledge of living authors would soon occasion injustice, which he would not feel the less to be injustice, because such persons might not, perhaps, regard the mentioning of their names by one who has made more use of their discoveries than their opinions as any honour.

The author intended to have added two illustrative notes. The former of these, referred to at page 18, consisted of a development of a natural method of the derivation of crystalline forms, in conformity to the laws of polarised action stated in the text. The other, referred to at page 168, was intended to consist of a translation of a part of the TIMÆUS of PLATO. Both are omitted in consequence of the unexpected magnitude to which the book has grown. For the same reason, also, the proof of what is frequently alluded to in the work, that positive polarity chiefly arranges parts developed under its influence in symmetrical positions in relation to an axis, while negative polarity (tending always to the development of an equator) occasions expansion and confluence; and the investigation of the development of embryos and of organic structures, have not been entered on. Besides occasioning such omissions, the reader will probably find also, that the attempt to abbreviate has given an intolerable *hardness* to the stile in which the book is written. But it was desirable that every thing except perspicuity should be sacrificed to brevity in a work like this, which may be considered as one continued illustration throughout, any part of which, viewed by itself, might seem eminently strange. What, for instance, might almost any one think were he to open the book for the first time at page 209, as a friend chanced to do, lifting up some sheets which were lying on the table? To have pled the cause of all such statements, however, or to have tempered them so as to suit the reader's liking rather than my own, would have expanded the work to several volumes, or have demanded the omission of many illustrations, which may be gathered from every region of nature in such profusion, that it was found difficult to bring the work to a close, even after it had attained double the size which was originally contemplated. I beg, therefore, to request the reader, if he propose to form his opinion of this work by reading a few pages only, as is very natural on taking up a volume by an unknown author, not to open it at random, nor even to choose the first pages, for they, in fact, consist of generalized matter, and cannot be rightly understood until the whole work has been perused, but rather to read page 528 and the two which follow, where, to serve the purposes of a particular argument, a condensed statement of the system is given in a few words. If he feel disposed to be at more pains than to read a few pages, I would only make this further request, to which the motto on the title-page is the answer of Socrates by Plato, Μεμνημένον ὡς ὁ λέγων ἐγὼ ὑμεῖς τε οἱ κριταὶ φύσιν ἀνθρωπίνην ἔχομεν, ὥστε περὶ τουτων τὸν εἰκότα μῦθον ἀποδεχομένους πρέπει τούτου μηδὲν ἔτι πέρα ζητεῖν.

ST ANDREWS, *May* 1830.

DIRECTIONS TO BINDER.

PLATE I. to face p. 627.
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ERRATA.

Page 4, line 17, *for* this *read* the—p. 9, second last line of note, *supply* evidence *after* such—p. 14, l. 32, for *destiny* read *density*—p. 50, l. 12, *for* exposition *read* opposition—p. 64, l. 22, *for* there are more, particularly four, aspects *read* there are particularly four aspects—p. 96, l. 25, *for* of the axis, *read* of the prism,—p. 103, l. 5, *for* $2_3 : 3_2$. *read* $2^3 : 3^2$.—p. 136, l. 11, *for* rays *read* rings—p. 144, *after the last word supply* one—p. 170, l. 3, *for* change *read* charge—p. 200, l. 30, *for* 1° ; *read* 1 ;—p. 215, l. 21, *for* molecule *read* molecules—p. 238, l. 19, *for* Fig. 39, *read* Fig. 37,—p. 253, l. 35, *for* 20.7, *read* 29.7,—p. 276, l. 17, for *Hyposulphuric* read *Hyposulphureous*—p. 476, last line, *for* protoxide *read* peroxide—p. 600, l. 18, *delete* and

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The nature and tendency of mind's action may be learned by viewing physical phenomena as a sensible exemplar of the economy of mind, which cannot be directly observed—action of matter consists in three functions—1. A nascent or active body during development, imitates itself as it existed the moment before, by which specific identity is maintained. 2. It imitates surrounding bodies whence the harmony of contiguous substances arises. 3. It imitates the form of the atom of light which is spherical, and is universally present, in virtue of which it tends, so far as circumstances permit, to become spherical or most perfect in form—imitation, a paramount tendency in mind—always when truly active mind exists simultaneously in a double state, viz. of perception on the one hand, and of sensibility as its substratum on the other—but the state of sensibility existing can only be discovered when the accompanying perception is that of the mind itself—happiness is the state of sensibility proper to a mind acting wholly according to its nature—misery arises from a laceration of the mind's true nature—tenor of a truly instinctive life described—instincts peculiar to man are desire of religion, and desire of virtue—mental phenomena are developed by the tripartite law of imitation exemplified in atomic phenomena—1. Self-imitative states of mind are the feeling of identity, memory, habit—this the lowest era of mental action—these modified by collateral perceptions are suggestion, imagination—2. States of mind excited by imitation of surrounding minds are the social emotions—3. States of mind excited by the presence of the Deity (exemplified by the influence of light on visible things), are the perception of truth, moral approbation—The same law is then applied to the

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phenomena of taste—the feeling of beauty anterior to the cogitative process by which fitness is discovered—two classes of beautiful objects, viz. such as are kaleidoscopic or possess merely forms and colours which please the eye, and such as are grand, or graceful, or are expressive of mind—the former depends upon superficies, the latter upon lines or edges—those superficies are most beautiful which are most harmonious with or can be imitated in the radiant tissue which constitutes the sensorium most perfectly, those lines are the most graceful which make the nearest approach in their forms to the axis of the cerebral column—these principles shewn to explain the phenomena of sculpture, painting, music, and architecture—our feelings of sensible beauty are therefore limited by our organization—the observation of every thing which has fitness for its existence would certainly excite that very pleasant state of mind which induces us to say that the object which awakes it is beautiful, if the mind could enter into that body, or derive a sensorium from it, which could be easily conformed to it, or modelled after it—hence while our mind continues embodied, we can form but a poor estimate of what creation really is, or of our own capacity to enjoy its beauty—hence also the using our taste as a standard by which to judge all things, is one of the greatest blunders of philosophy—Having shewn that visible beauty arises from the excited parts of the sensorium becoming assimilated to the visible object said on this account to be beautiful, it is inferred that the feeling of moral beauty, or beauty not pictorial, arises from an imitation in the state of the mind itself of that which it admires—love is admiration of beauty along with the social desire to be similar to or identified with the object loved—the love of the Supreme Being therefore is the mechanism by which we become likened to Him and are destined to grow in goodness and happiness—conclusion, 543—616

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BOOK I.

ON THE

STRUCTURE AND ACTION OF MATTER.

OF MATTER.

1. The phenomena of Physics, Chemistry, and Physiology, have usually led reflecting men to assume the existence of three orders of substances or agents. Of these one, which is named Mind, cannot be made an object of sense, nor known except by consciousness, and its action impressed upon the others; the second, including Light, Electricity, and Magnetism, may be shewn to possess in certain circumstances the properties of resistance and elasticity, but cannot be made opaque so as to be visible, nor be directly felt by the sense of touch; while the third, of which our bodily organs themselves consist, is (and as will be afterwards shewn for this very reason) both visible and tangible. These three orders of agents are, however, generally treated of as belonging to two classes, viz. *mind* and *matter*, the properties of the former being sensibility and cogitation, of the latter, extension, divisibility, elasticity, &c. and a liability to be acted on by mind. In the three first books of the following work we shall occupy ourselves with an investigation of the phenomena of matter, while the fourth will contain an inquiry as to the existence, and a cursory view of the phenomena of mind.

2. On instituting an inquiry as to the qualities possessed

by matter, that which at once strikes us as the most obvious is *form*. For since matter is a *substance* extended in space, and space is *nothing* but mere extension in length, breadth, and depth, it follows that matter is an extension of a nature dissimilar to space, and therefore on every side, at the confines between space and matter, a superficies must be developed as a boundary of the substantial thing. But the sum of such superficies constitutes a form: every portion of matter, therefore, surrounded by a medium dissimilar to itself, must have a form; and unless we are to base philosophy on that which is inconceivable, we must admit that this form which limits its substance, defines also the extent of that body as an agent.

Another property which matter in one state or other possesses universally, is *elasticity*, or the capacity of suffering an alteration of form, and of making an effort spontaneously to recover itself when the force which constrained it is removed. From this most important property we learn, that matter is not indifferent to every state of existence, but possesses one condition more congenial to its nature than another, in virtue of which it tends to this natural state as often as it has by any accident been driven out of it. The action of matter, therefore, does not consist only in a mere yielding to an extrinsic impulse, and in remaining for ever in the state into which it has been thrown, but in its capacity to suffer such a change from without, together with that of subsequently making a conatus from within, to recover a certain condition more natural to it than another.

As has been already stated, matter exists in two states, differing from each other in so many features, that it is necessary to consider them individually. The one may be called *Hard* or *Atomic Matter*, and the other *Motorial* or *Subtile Matter*; terms, the former of which corresponds to body as commonly understood, and the latter to the "subtile spirit" described in the last paragraph of the PRINCIPIA OF NEWTON, or to that class of bodies often named Imponderable Substances, with the exclusion of heat.

OF ATOMIC MATTER.

3. When any body is stript of the subtile matter which penetrates its pores and invests it, to which it owes its colour, degree of hardness, specific form, electrical state, and other sensible or chemical properties, there remains a mass of impenetrable particles, which, taken individually, are so excessively minute, that it is difficult to compare them with any visible magnitude. One grain weight of gold may be extended over a surface of five square feet, without any visible intervals between the particles, though it be generally believed that a particle of gold is more than a hundred times as heavy as one of hydrogen gas; and, therefore, we should infer much larger also. As far down as we are able to carry microscopical observation, organized forms are discovered so minute, that it requires good eyes and glasses to render them visible; and any animal, or plant, however simple, must certainly be composed of a great many of the least parts into which matter is ultimately divided.

4. But whatever be their actual magnitude, it is to be remarked of the particles of matter, that they possess different weights, and, to judge from all phenomena, different magnitudes and forms also, in different species of chemical and natural bodies; while in the same body, they always possess these qualities the same. These facts, the truth of which has been generally anticipated by philosophers, have, within these few years, been placed beyond doubt by the discovery of the combining ratios of chemical substance—a discovery which, along with those simultaneously made in physical optics and electro-magnetism, or the dynamics of subtile matter, forms the grand achievement of this age; and the doctrines advanced in this work derive their evidence chiefly from these sources.

5. With regard to the nature of these specific particles, a question has often been agitated, which is of the greatest

importance in physics. Are these different sorts of that impenetrable substance called matter? or do all the distinctive qualities of natural and chemical bodies arise from differences in the form and arrangement of ultimate parts, which are universally the same in the quality of the naked substance of which they are constituted? Were it necessary to entertain the opinion, that there really exist portions of matter such, that, though their forms, magnitudes, and mathematical conditions generally, were every way the same, they remained heterogeneous still, then we could no longer cultivate Philosophy under the inspiring hope that she might one day reveal to us the structure of the universe. For if we admitted into the constitution of terraqueous bodies several kinds of matter, essentially distinct from each other, there could be no just limits to conjecture as to the nature and variety of the matter which existed in other regions of space; and to explain this phenomena of the heavens, we might have recourse to as many hypotheses as there are stars, not one of which could be either proved or disproved. Sir H. Davy says, in his Elements of Chemical Philosophy, which are now rendered infinitely precious, "If that sublime idea of the ancient philosophers, which has been sanctioned by the approbation of Newton, should be true, namely, that there is only one species of matter, the different chemical, as well as mechanical, forms of which are owing to the different arrangements of its particles, then a method of analysing these forms may probably be found in their relations to radiant matter." (P. 223.)

It is the principal object of this work to attempt the analysis here anticipated by this great philosopher and chemist, to shew that there is only one kind of impenetrable matter; that it may be ultimately divided into atoms, uniform in size and shape; and that the particles of chemical and natural bodies, commonly called their atoms, are structures constituted of these ultimate atoms, more or less powerfully retained in union, and admitting of decomposition or not, according to the manner in which they are associated, or the method of analysis to which they are subjected.

6. As to the nature of the ultimate atom, little need be said. It may be inferred, that its substance is physically impenetrable on every side, and that, considered as a whole, it is elastic, or yields to an impulse or pressure, and exerts a force to resume its original form, when that which altered its shape is removed. This property, according to the mode of its action, gives rise to two classes of phenomena, which, at first sight, seem a little different. When the recoil, as well as the initial movement, is observed, the substance is at once recognised as *elastic*; but when, by sustaining the force which impresses it, or by binding it down in the compressed state, the recoil is prevented, and the movement of yielding only is observed, the substance is recognised as *plastic*. Thus, if a steel-spring be touched, the vibrations which ensue indicate its elasticity; but if it be rendered magnetic, while it seeks about yielding in every direction towards iron, the same property indicates its plastic nature.

The view which has now been given of the atomic structure of matter, will not interfere with the speculations of those who are curious in such questions as its infinite divisibility. It is only asserted, that these atoms do not occur in nature divided, and that the cause of this is something else than the hypothesis of Boscovich, who otherwise entertains the same view, that they are unextended. It may also be remarked, that they are different from the atoms of Des Cartes, the impossibility of whose existence he treats of, when he says, " Cognoscimus etiam fieri non posse ut aliquæ atomi sive materiæ partes ex natura sua indivisibiles existant." (Princip. p. 31.) It may be admitted, that there is no limit to the division of an atom, in as far as its own nature is concerned. It will serve the purposes of physics and chemistry well enough to maintain that atoms do not occur divided, because there are no bodies in nature harder than themselves to break them down.

7. If it be thought by any one, that, in cases of violent attrition and percussion, accidents might occur to these small bodies, and that it would be interesting to know what would become of the fragments, it may be suggested, for the consideration of such virtuosos, whether it be not probable, that, when a bit was broken off an atom, the whole was changed into subtile matter. This hypothesis would, at least, exonerate the view now advanced of the charge, that much injury might be done by the destruction of atoms; or if it be thought that no substitution could compensate for the loss of solid matter, it may still be urged that, perhaps, an atom is a hollow shell of subtile matter in a concrete state; that the quantity of solid matter entering into its composition is exceedingly small; and that, as atomic matter, when it cannot exist as such, changes into subtile matter, so subtile matter, in other circumstances, may concrete into atomic matter. Our eyes are too bad for seeing such things, though they really were; and perhaps those who would be content to believe them, do no more injury to sound philosophy than those who pretend to deny them. This much may be safely affirmed with old authors, that the ultimate atoms of bodies are *longe invisibiles.*

OF SUBTILE MATTER.

8. Atomic matter is always surrounded by an atmosphere of an elastic substance of a very subtile nature, extending to a certain distance beyond the hard nucleus which it invests, and increasing in density in the duplicate ratio of its depth. It is neither visible nor ponderable, but it is the cause both of colour and weight; nor is it impenetrable to every body, nor does it oppose any sensible resistance to the sense of touch. The hand may be made to approach the strongest magnet, without being able to discover that any substance exists beyond the surface of the iron. Its subtile matter is nowise

impenetrable to the hand, but it is impenetrable to matter of its own kind, and a similar pole of another magnet demands a great force, before it can be pressed through the subtile matter which invests them both. If, again, not similar, but consecutive poles, be presented to each other, the evidence of an intermediate mechanism is no less satisfactory. The two consecutive portions of subtile matter being in such a state that an union of both is necessary to produce the condition of natural repose, they become confluent, and the masses of iron to which they are attached are consequently drawn together. They are said mutually to attract each other; but we are not to suppose that this arises from any occult quality, virtue, or power, proper to the dense bodies meeting each other, which is not itself a substance submitting to certain physical movements, like the masses of iron themselves. Neither are we to believe that the phenomenon is explained, when we are told that the iron and the magnet attract each other, because they are near each other. To explain such phenomena by a discourse on the relation between iron and a magnet, with a view to shew that motion is produced by a simple proximity in space, without the aid of any intervening mechanism, is not in any degree satisfactory; and to ascribe our unwillingness to receive this view to a natural love of mystery, which is always pleased to imagine the agency of invisible powers, is to simplify philosophy at a great expense, and at once to accuse us of a fondness for mystery, and to aggravate our weakness by imposing an excessive mystery upon us. It is true, that the power which causes a phenomenon is nothing more than an event which precedes it; but between all physical phenomena, which are mutually dependent, there is a material mechanism continuous in space. A magnet attracts a bit of iron, because their subtile parts, though they do not possess colour, and are not seen or felt (except by the proper apparatus of touch which is a polarity of the same kind), are in contact. Physical motion is never produced where there is not immediate contact of the body moved. These are certainly the ideas of the transference of motion, which are most grateful to a common understanding; and that the philosophy which would banish from physics the existence of what have been called imponderable substances is not suitable for the purposes of science, is shewn by the fact, that those who are most conversant with phenomena are not contented to believe that visible parts are all that actually exist, and all the mechanism employed in developing the phenomenon.

Like atomic matter, subtile matter is ultimately of one kind, and its functions are limited to a few modes of action. But it is modified in the phenomena which it produces, according to the region of the atom, or group of atoms, which it invests; and every species of body, according to its molecular constitutions modifies in a specific manner the subtile matter proper to the ultimate atoms of which it consists. Polarity, attraction, repulsion, and rotation, are the classes of motion to which subtile matter gives rise, according to the state in which it exists in the medium where the motion takes place; and it may be remarked generally, that when the subtile matter of different bodies is *in æquilibrio*, as, for instance, when their electrical states are the same, they repel or attract each other only when they have a natural analogy of form; that is, in as far as their subtile matter, viewed in its specific modification, is concerned; but at a certain degree of nearness or distance, difference of specific structure is overcome by the generic sameness of all bodies, because they are ultimately formed of similar atoms.

The ultimate atom, like the grosser bodies to which it gives rise, is composed of a nucleus of hard matter invested by subtile matter; and to it the phenomena of attraction, repulsion, and polarity belong, and act according to the same laws as in more obvious cases. As these laws are the syllables of the laws of nature, and must become the guide of our researches among the insensible movements of light and heat, and chemical union, it is necessary to investigate them somewhat in detail [*].

10. *Subtile matter, when attached to the angles of atomic matter, gives rise to the phenomena of attraction and permanent adhesion, and is polarized to a certain distance around the atomic body.* The softer any small steel solid is made, so as to admit of as free a distribution of its magnetism as possible, the more highly is its attractive polarity confined to its *angles;* and there is every reason to believe, that, when a polarized attraction is exhibited on a *surface*, it is

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[*] The experiments by which the following results as to polarized action were obtained, were performed by the aid of geometrical forms, sometimes made of solid steel, sometimes of steel-plates cemented together by a magnetic cement, and, at other times, of needles united in a similar manner, the metal being always softened. The magnetism was communicated by bringing a magnet near them while they were revolving at the rate of four or five thousand times in a minute, at the extremity of a glass-spindle. By imparting to them so rapid a rotation, the magnetism might be regarded as simultaneously communicated to opposite regions, and an irregular distribution from induction was prevented. The resulting state of the magnetism, after the magnetised form had been left to repose for some time, was ascertained by the repulsion upwards of a hollow steel-cylinder full of air, with an opening at bottom, enclosed in a small glass-tube filled with spirit of wine, and with a screwing apparatus at top, by elevating or depressing which the specific gravity of the needle could always be brought to that of the spirit in which it moved. Thus, the weight of the needle did not interfere with its ascent in the spirit, which being read off on a scale, attached like that of a thermometer, though, of course, graduated on a different principle, gave very satisfactory indications of the amount of the repulsion. But I believe the instrument is susceptible of still greater improvement, and it need not be described in detail. It will be perceived, however, that the following generalizations are neither altogether the result of new experiments, nor of any experiments, but deductions from both, along with the consideration of natural phenomena as to the probable mechanism of subtile matter. To limit our researches by actual experiment, is to exclude ourselves from the inquiry. Astronomers attempt to discover the weight of the heavenly bodies without the use of the balance. The atoms of bodies are equally inaccessible; and we must content ourselves with such as we can command.

only in regard of that surface being a congeries of angular points, which no polishing can destroy. In the common magnetic needle, the poles are not at the angles; but the needle, as commonly made, is an unnatural form, combining subtile matter both in its polarized and circulated state, as will be afterwards shown. If the ultimate atom, then, possess angles, they will exhibit the power of attraction and permanent adhesion analogous to that of iron. Every polarized attraction has, indeed, its corresponding repulsion; but the only agency of such a repulsion is to regulate the positions in which bodies shall apply themselves to each other. On the great scale, the attractive principle is universally attractive.

When two consecutive angles act upon each other, their force towards union is inversely as the square of the distance between them. When a polarized body attracts another which is not polarized, but is susceptible of being attracted, the force by which it is solicited seems to be as the cube of its distance. When two polarized angles of one approach and unite with two polarized angles of another, they approach and are retained in cohesion by a force in a higher ratio. When three meet and unite with three, they observe a ratio still higher; and so on. If, then, the particles of bodies be angular, the various phenomena of cohesion which they exhibit may be explained by the number of angles which cohere in a given space.

The whole analogy of nature induces the belief, that the smallest parts of matter are very highly angular. Forms with rounded faces are only met with in bodies of a most complicated structure,—such as the eye, fruits, and other organized forms, or those which require a spheroidal form for the equilibrium of their motions, as the heavenly bodies. The more minutely we comminute any body, the more highly angular do its parts become. The primitive forms of crystals are generally more acutely angular than those in which they occur in nature; and even in highly polygonal tessular forms, which are the most perfect productions of inorganic nature, a tendency towards the sphere is effected only by increasing the number of angles. All things considered, it would be very strange, and contrary to the whole aspect of nature, if the ultimate particles of bodies had round faces, and forms which were either spherical, oblate, or otherwise than highly angular. Entertaining the belief, in the mean time, that they do possess angles, these we are to regard as the foci of the permanently attractive principle.

Subtile matter, when giving rise to the phenomena of attraction and permanent cohesion, has obtained a variety of names, according to the circumstances in which it acts. Thus, it is called the power of *gravitation*, when it causes bodies tend to unite with the earth, or operates between the heavenly masses; of *aggregation*, when it causes particles of the same species more or less distant, to approach towards forming one volume; of *crystallization*, when it operates at the distance at which it is polarized, and arranges them symmetrically; of *cohesion*, when it retains them in union; and of *magnetism*, when it belongs to iron. These different names are very useful, and are philosophically accurate. They do not, however, express different powers, but the same, producing the various phenomena, which are the proper offspring of its existence in the circumstances implied. All bodies are attracted towards the earth, and the heavenly bodies towards each other, because subtile matter acts mutually when investing similar forms; and all bodies being ultimately composed of similar atoms, are in this regard similar. Gravitation, then, is only a generic aggregation. But as these atoms are arranged in different ways, and give rise to various structures, similar structures are attracted towards each other in preference to dissimilar ones; because, while they have all the generic attraction of the latter, they have a specific recognition of each other, in consequence of a specific similarity of form which the others want. Crystallization is the same power operating at the distance at which it is polarized, and causing the particles to come together in a conformable manner. Cohesion is merely the sustained action of the same power; and it will afterwards be shewn, that there is something in the nature of iron to occasion a more vigorous exhibition of polarized attraction than other bodies; but there is no reason why we should not make use of its polarization, which is the only one easily examined, and deduce the general phenomena of polarity from it.

11. *Two polarized angles, united by a line or edge, possess their subtile matter in states consecutive to each other.* With this phenomenon every one is familiar in the common magnetic needle. There are narrow limits, however, within which only the proposition is true. If the length of the line be greater in relation to the area of its transverse section than a certain quantity, it is more natural for a repetition of poles to occur along the axis, than for the whole to contain two poles only at its extremities.

From the fact, that the extremities in an individual axis are consecutive to each other, it follows, that an axis composed of easily flexible materials can only continue to exist while it remains straight; for on departure from an opposition of the consecutive poles, they must tend to unite (if within the sphere of mutual action) on that side on which the approach has been made; and as the axis becomes more bent, this tendency must increase till the axis be bent into a circle. When the subtile matter of a polarized axis is thus disposed of in a circle, it may be said to be circulated.

Let A X (Fig. 1.) be a polarized axis composed of a flexible substance. As soon as the direct opposition of A and X is destroyed, these points being consecutive to each other, approach and unite, and the axis is resolved into a circle such as C. When attached to matter in this form, the subtile principle is found to possess one polarity on the external aspect or peripheral angles, and another on the internal aspect, or in the axis on both sides of the equator. The radius is now the polarized axis.

12. *The attractive energy of a body is very much diminished by subjecting it to a very rapid vibratory motion.* It is well known, that, when a vigorous magnet is made to ring, by being struck for some time, it loses much of its force. It is affected in a similar manner as if it had been heated, which, I will afterwards attempt to shew, is only the exciting of tremor in its ultimate atoms. I have not been able to detect any diminution of energy, but rather the reverse, by a rotatory motion. When a polarized bipyramid was made to revolve four or five thousand times in a minute, and for half an hour, its polarity seemed rather to have acquired additional symmetry, unity, and strength.

13. *Subtile matter, when attached to the surfaces of atomic matter, or the areas between the angles and edges, gives rise to the phenomena of repulsion and rarefaction, and is polarized to a certain distance on opposite sides of a neutral plane.* The repulsive principle, like the attractive, receives different names, according to its specific modifications,—such as light, electricity, galvanism, the force of affinity, the force which causes fermentation; and it is often not distinguished from heat. In this work, it is assumed that heat, though it instantly induces a definite change in the distribution of subtile matter, is in reality nothing more than a vibratory motion in atomic matter. No fault need be found with the names light, electricity, galvanism, chemical affinity; but if these be admitted, many others ought also to be introduced; for every species of body modifies its subtile matter specifically, and has an electricity of its own.

As all bodies, however, (being composed of similar atoms) have universally similar facets to which the repulsive energy is proper, all the different species of electricity recognise each other more readily than the different species of attraction, for the angles may be very dissimilar, one angle being often formed by the union of others of a more acute form. That electricity and light belong to the *areas*, and not the *angles* of particles, is inferred from the fact, that the electric fluid is rapidly dissipated from angles; and from the necessity of rounding and polishing as highly as possible those bodies which are to be rendered very highly electric or illuminated.

It has been said, that the surface is polarized on opposite aspects, or if it be positive on one side, it is negative on the other. Thus, let two bodies, which are not in the same electric state, be applied to each other; if one face be found positive, the other is found negative, and the series of excited laminæ, if the substance be capable of giving rise to polarized axes, is continued backwards on both sides, from the region of excitement to a certain distance. Between the poles, as usual, there is a neutral region, which, in this case, is a plane. If, again, a thin film be exposed to the light, so that the repulsive fluid, proper to its ultimate atoms, shall be excited into a polarized axis, one colour will be seen on that side, and on the other the consecutive tint, or such an one as, when united to the first, neutralizes the polarity, and removes the chromatic excitement. The phenomena are perfectly analogous. But there is the same difference between light and electricity, that there is between gravitation and aggregation. Light and gravitation are the phenomena produced by the specific subtile principle of the ultimate atom; electricity and aggregation are the phenomena produced by the subtile principle specifically modified by different sorts of compound particles.

14. *The form of the subtile matter investing a portion of atomic matter whose magnitude is inconsiderable is a sphere, its destiny increasing in the duplicate ratio of its depth; and when two polarized axes are confluent, by being within the sphere of mutual action, the loci of equal density constitute a*

lemniscoid. When the magnetometer is moved round a magnetic angle of great power compared with itself, in any direction, the lower extremity of the index describes a circle of which the magnetic point is the centre. When spheres, however, that are mutually impenetrable or repulsive, are pressed together, they seem to compress each other into oblate figures. Consecutive spheres, on the other hand, when made to unite or retire, draw out each other into prolate or ovate figures. To trace the loci of equal intensity, is an experiment of greater delicacy than I have been able to perform. But every indication led to the conclusion which has been ascertained by Mr Herschel, in reference to the atomic repulsive principle, that the loci of equal tint or intensity in two axes partly homologated, are expressed by a lemniscoid, or ellipse compressed in the region of the transverse axis, and of such a property that the product of the two lines drawn from the foci to any point in the curve is a constant quantity.

15. *Forms of a bipyramidal aspect only are capable of becoming polarized in a symmetrical and quiescent manner, or the action of polarity is to develope forms which are symmetrical and of a bipyramidal aspect.* The better to investigate the phenomena of polarized attractions, I heedlessly constructed a number of the most eminent forms of geometry and crystallography; but, on magnetizing the forms which were not of a bipyramidal character, was perpetually met by poles towards the centres of lines and faces; and in situations, which, except in so far as they were a congeries of angles, were incapable of entertaining the attractive principle. Wherever poles were thus developed, I relieved the form by substituting angles in their place; and thus was speedily conducted to a bipyramidal form, as the limit of the reduction in which the distribution of the polarity became symmetrical and quiescent.

Let a very flat prism or angular disk of very soft steel, while revolving rapidly, be polarized, by presenting the pole of a magnet in the plane of its revolution. Upon examination, all the angles of the circumference will be found to have acquired a polarity of the same name, while, at the centre on both sides, will be found a polarity of an opposite name; and in whatever other way the magnetic polarity be induced upon it, it will either destroy itself, or be developed awkwardly, until this limit be attained.

It is also important to remark, that such a central polarity may be so covered in by spheres of subtile matter of an opposite polarity, belonging to the angles of the circumference, that it is inaccessible to a consecutive pole of a body made to approach it, unless when the peripheral sphere or annulus of subtile matter is violently penetrated. Thus I have frequently magnetized surfaces of tempered steel, so that the index of the magnetometer, when its incident pole was of the same name with that of the peripheral angles, could not be suffered to come within the central sphere of attraction, though a strong one existed there. The central and consecutive sphere was, as it were, covered in on all sides by the subtile matter attached to the circumference, which, being of a similar polarity, repelled the index. But when I brought down the instrument, through a fall of several inches, the momentum which the index thus acquired was now able to carry it through the repulsion emanating from the peripheral angles, whereupon t instantly perched upon the centre with a velocity proportional to the central attraction which solicitated it. When, again, it was relieved from its engagement, though removed as nearly as possible in the direction of the axis, as soon as it came under the influence of the peripheral repulsion it flew off as if explosively. When the polar disk of a magnet is of considerable extent, it will be found in a similar condition; and if it be composed of laminæ, that in the centre will be found in a neutralized state, like the colourless lines of a crystalline plate viewed in polarized light along the axis of polarization (or the axis of no polarization). Since a polarity is found at the centres of these tables, had they power to alter their shapes so as to assume a form of equilibrium, their centre would be elevated into a solid angle on both sides; that is, they would become the equators of symmetrical or double pyramids, (which, for the sake of perspicuity, and not to interfere with the language of geometry,) I shall continue to denominate bipyramids. Such forms, whatever be the number of their angles, may be regularly and permanently polarized at once; and whatever other forms an attempt is made to polarize regularly, they must be constantly altered and relieved till they become simple or compound bipyramids or figures with triangular faces, one region of which may be regarded as the equatorial or prismatic, in reference to another, which is regarded as the polar or pyramidal. I need not describe the various forms which I inconsiderately prepared and subjected to experiment, with a view to ascertain the state of their resultant polarity. Accustomed to regard the magnetic needle as a regular solid, and not as an edge of a solid, which it really is, I always expected opposite poles in points diametrically opposite; and this expectation made a very obvious truth somewhat inaccessible. Suffice it to say, that, having found that small forms, constituted of edges and angles only, served the purposes of investigation better than forms of solid steel, I built them of softened needles, united by cement, in which iron filings were mixed, covering the angles with iron filings while the cement was soft; then magnetised them in the way which has been mentioned; and when time had been allowed for the subtile fluid to equalize itself, I corrected and relieved them, by modifying their forms at a spirit lamp. Many interesting and nameless figures were evolved, some of which I have since had the pleasure of recognising in what are believed in this work to be the forms of the particles of some chemical bodies, a pleasure not then anticipated; but every form was ultimately laid aside with a bipyramidal habit, or a tessular form, in which the faces were triangular. Thus, a cube to relieve the polarity which emanated from the centre of the faces, was, by enlarging its form, changed into a hexædral trigonal icositetrædron, or, by diminishing it, into a body of a re-entrant form of the same character. In observing the development of the crystalline forms of common salt, during the evaporation of a drop of salt water under the microscope, the production of the same forms in connection with the cube will be constantly observed. The re-entrant icositetrædron, had the matter which composes it power to alter its shape in obedience to its polarity, would break up into twenty tetrædrons and an octædron: and the polarity of these tetrædrons would only be in æquilibrio when the substance which composed them had expanded and contracted till all the angles became equidistant,—that is, the tetrædrons regular. (See Note A.)

The tetrædron (Fig. 2.) differs from all other forms, in being quite destitute of any region which could be recognised as the equator. Its polarity cannot be in a state of repose, nor can it be sustained in a state of insulated existence, but by the interposition of a repulsive medium between contiguous particles. If permitted to approach each other, two would immediately unite; and thus a triangular bipyramid (Fig. 3.) would result, which is obviously capable of a symmetrical polarity, and which, if it be not quiescent, it is only because its form is too highly positive, as will be afterwards explained. In other instances, five would unite by an edge, and give rise to a pentagonal bipyramid (Fig. 4.); or six (Fig. 6.), and enclose a space, which is a triangular bipyramid, isamorphous with Fig. 3, and having its faces covered by an angular form; or eight, and give rise to an octædral space covered by eight triangular pyramids (Fig. 5.), thus constituting a trigonal icositetrædron with the edges of the fundamental octædron re-entrant; or ten (Fig. 7.), and give rise to a pentagonal bipyramidal space, isamorphous with (Fig. 4.), each face being covered with a triangular pyramid. Thus it appears, that the tetrædron, which is the ultimate form of angular bodies, when invested with subtile matter, may be preserved only by being kept from access to others, as by each being invested by a repulsive sphere, and it is most fertile of bipyramidal forms.

16. *In forms regularly polarized, the subtile matter is in the same state on both the polar regions, but in a consecutive state on the equatorial region.* This proposition is merely an extension of the principle developed in the last. Familiarity with the structure of the magnetic needle renders its admission somewhat difficult; but the needle, as has been already stated, is analogous to the terminal edge of a solid. We are at once able to see how admirably such a distribution sustains the permanency of a form composed of parts which would separate, were it not for the attraction retaining them in union. Suppose a bipyramid to be composed of laminæ laid on both sides of the equator, and decreasing symmetrically till the summit is formed on both sides, then the development of two polarities of the same name at the poles, and one of another name at the equator, produces the same effect to impart stability to the form, as if two caps were put upon the poles, and braced together by stays attached to the equator. Or if we suppose that a terminal edge is really a polarized axis, its action must tend in an exquisite manner to sustain the identity of the form during successive increments.

From this it follows, that the solid axis of a polarized form is not a polarized axis, but rather two, one of which is an image of the other, and which are united in the centre, not by consecutive but by similar poles; and hence similar phenomena of polarization must be obtained by inspecting the state of either extremity of the axis of a molecule or crystal possessing polarity. A terminal edge, on the other hand, has poles which, like a polarized axis, draw particles to one extremity or the other in a fixed position, and demand their attachment to the polar or equatorial region, according as their state is most consecutive to the one or the other.

From this a very important consequence results. A symmetrical molecule is kept together by its superficial polarity, and, as it were, depressed in the direction of the axis. By its internal polarity, it is pressed to shoot out in the direction of the axis, for the two poles, possessing the subtile matter in a non-consecutive state, must repel each other in the direction of the line joining them, that is, the axis; and whatever number of such subordinate axes may be repeated in the course of length of the axis of the form, the non-consecutive poles must all be applied to each other, and the effect of the development of subordinate polarized axes, or the subdivisions of the whole axis of the molecule or crystal into shorter axes, is merely to increase the force which expands the whole axis,—unless, indeed, some of the parts containing the subordinate axes were permitted to turn through half a revolution, and thus give unity to the whole axis again. After this, a recurrence of the circumstances which subdivided the axis before, may subdivide it again; and the same semi-revolution of those particles which are free to move take place, and the relief of the form ensue. When the repulsion along the axis becomes greater than the cohesion produced by the consecutive polarity (which is in reality circulated) between the poles and equator, the molecule breaks up into several, and this is part of the mechanism by which polarized action tends to develope and conserve the highly polygonal tessular, or spheroidal form. During the development of a molecular and crystalline form, the attractive influence proper to the angles of the particles of which it consists tends to produce a certain form most compatible with their shapes. The general polarity of the mass of particles already aggregated, on the other hand, tends constantly to modify and move towards the spherical the particles successively attached; and when the spherical or polygonal tessular has not been attained, in consequence of the superior influence of angularity of form of the particles, the repulsive influence remains in the molecule in a state of polarized excitement.

17. *A molecule is in æquilibrio, when its form is such that its equatorial polarity, or that connected with its prismatic parts, balances its polar, or that connected with its terminal or pyramidal parts; and the object of chemical union and decomposition is to give rise to such a balance* Suppose the forms of the particles of bodies to be such, that some are highly bipyramidal *; others, a sort of prisms, terminated by negative pyramids, and little else than equatorial annuli, as, for instance, when five of the triangular pyramids are bent down upon each other (Fig. 8.); others, intermediate in the balance of their prismatic and pyramidal parts, as, for instance, the pentagonal bipyramid formerly alluded to, (Fig. 4.). These forms are more or less disposed for insulated existence, according as the ratio of their equatorial and terminal polarities more or less nearly approaches that of neutralization.

One of the natural molecules, which seems to be most highly fitted for insulated existence, in consequence of the perfection of its form, is the crystallizing molecule of carbon, or the diamond, which, according to the views advanced respecting carbon in this work, is a most beautiful body of a spherical contour (Fig. 66.), bounded by 60 faces, which are equilateral triangles, or thirty faces, which are lozenges of 60 and 120 degrees. This will, in the mean time, serve to illustrate the position, that the form of polarized equilibrium, in which the balance between the motorial fluid of the equatorial parts of the form, and that proper to the polar is most perfectly established, is when the form has approximated most nearly to the sphere. Hence the three bodies, which have just been alluded to, will unite with each other, because each can, in some degree, relieve the electric state of the other. Thus, the frustular form (Fig. 8.) evidently wants pyramidal polarity, and will unite with the pentagonal bipyramid (Fig. 4.)

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* The reader will see the necessity I am under of assuming, in the mean time, that the particles of the bodies are angular, for if they were not angular, it follows, from the principles already advanced, that they could neither gravitate, crystallize, nor cohere.

with avidity, the more especially as the re-entrant region of the one is conformable to the terminal region of the other; thus, a compound body (Fig. 9.) will result. The two pyramidal forms (Fig. 3. and 4.) will also unite, as in (Fig. 10 or 11.) because the resultant state of polarity, arising from the confluence of that proper to each, is more near to a state of neutrality than that possessed by either alone. There is, in fact, no limit to union of forms, but similarity of motorial state, or an excessive length of axis. Two forms having a polarity of the same name equally in excess, will not unite, because the resultant state is not more nearly quiescent; and between bodies in a similar state of excitement, if there be any action, there is a mutual repulsion only, except in cases of great contiguity, where angular cohesion takes place.

The affinity of bodies, however, or the force with which they unite, is by no means a measure of the force by which they are retained in union. Here another element must be considered, viz. the cohesion arising from the attractions emanating from the angles. This attraction does not in dissimilar bodies perform so important a function in determining to union; but when the dissimilar particles come into immediate contact, then they are clasped by the attractions of the angles of their most minute parts, or ultimate atoms, and applied edge to edge and face to face, and the cohesion and resistence to decomposition is great in proportion as the number of parts cohering is great, other things being equal. Thus, supposing the affinity between the two bipyramidal forms constituting the body (Fig. 10.) to be equal to that between the equatorial form and the pentagonal bipyramid constituting (Fig. 9.), the decomposition of the latter, nevertheless, would evidently be much more difficult than that of the former. Hence, harmony of form, as well as difference in motorial or electrical state, modifies the phenomena of decomposition; and, it may also be added, of union, for particles which belong to the same system of forms unite most readily in consequence of their specific analogy of form (§ 9.)

Chemical union, however, is not altogether confined to dissimilar particles. It often happens, that *particles*, by entering into union among themselves, can give rise to a *molecule*, whose polarity is in a much more quiescent state than the polarity of any particle taken separately; and when a substance is in this molecular state, as its electrical state is changed, so also is the range of its affinity modified. Thus, suppose a form (Fig. 12.) constituted of five of the triangular bipyramids, united by a terminal edge. In this state, it is very far from quiescence, wants symmetry, and must evidently be ill suited for insulated existence, and, consequently, be very parasitic, and have an extensive range of affinity. But a pair of such bodies united face to face (Fig. 13.), would give rise to a highly quiescent symmetrical molecule. It is quiescent, because there is a balance between equatorial and polar parts; and it is evidently symmetrical, being an icosaedron.

But in such a concrete form, a great many faces are pressed against each other; and, consequently, the repulsion emanating from these faces must be constantly tending to expand it. We may therefore expect, that when opportunity is afforded, the binate icosaedral molecule will expand so as to consist of the two particles united by five equatorial angles only (Fig. 14.). By this movement, twenty facets are relieved, and a form of great symmetry and electrical quiescence is still retained. But it now becomes accessible, in its equatorial region, to the incidence of five of the pentagonal bipyramids, (Fig. 4.); for it may be remarked, that the equatorial regions being concave, must be of an opposite electrical affection to the bipyramid, and they are also quite conformable to the equatorial edges of that form; from such an union, then, (Fig 15), a case of intense cohesion would result.

Such are the movements and combinations to which polarised action would give rise in bodies possessing such shapes. There are no other laws that limit the union of particles of chemical and natural bodies. Many of the simpler compounds consist of one particle of body united to one of another. Many of the most common substances, however, consist of one particle of one body united to two, three, four, five, six, seven, or ten, of another, as the case may be. But even in the rapid productions of the laboratory, which are in general very rude approximations to a state of symmetrical and quiescent union, compared with those of nature, the number of particles of two kinds only, implied in the constitution of one compound particle, is often very considerable. Thus, as will be afterwards shewn, while phosphoric acid consists of one particle of each of its elements, phosphatic acid consists of nine of the one, and ten of the other. Silica consists of four of oxygen and five of silicon. In a particle of malic acid, there are no fewer than 12 particles of carbon, and in a molecule of starch probably no fewer than 108. The ratio of the carbon with the other elements, however, is in both cases extremely simple, and the actual structure could never be determined by chemical analysis without other aid; while, in such a case as that of phosphoric and phosphatic acids, the utmost attention to analysis is demanded, and great care that the mind be free from prejudice and a disposition to confound or disregard them. Mutual harmony of form, and the disposition of electrical state, to evolve a symmetrical highly polygonal tessular molecule, are the only circumstances that modify the union of chemical substances. On this subject, which will be fully illustrated in the chemical details that follow, it is only necessary to remark farther, that as the terms electro-positive and electro-negative are already introduced into science, they are still retained in this work, the former to express the state of the subtile matter proper to pyramidal forms, of which, happily, it is not a little expressive; and the latter, that of expanded or equatorial parts, and of re-entrant regions, which are very naturally regarded as negative. Were there such bodies in nature, then, as those that have been mentioned, and were they arranged according to their electrical state, they would stand thus :—

Electro-positive.

The triangular bipyramid, Fig. 3.
The icosædron, Fig. 13.
The pentagonal bipyramid, Fig. 4.
The compound form, Fig. 15.
The binate molecule, Fig. 14.
The equatorial frustular form, Fig. 8.

Electro-negative.

The quality, intensity, or tension of a body's electricity, then, depends upon its form; but the quantity being determined by the number of unsuppressed facets which it possesses, depends upon the extent of its surface. Thus, the *intensity* of the electric state of the triangular bipyramid (Fig. 3.) is much greater than that of the icosædron (Fig 13.), because it is much farther from a state of repose or neutralization: but the *quantity* of electricity proper to the latter is much greater; and were two bodies isamorphous, but one possessed a greater number of faces than the other, that which had its faces most numerous would have its quantity of electricity, or its electric power, greatest. Thus, as will be afterwards shewn, potassium and sodium are isamorphous; but the surface of potassium is represented by 40, while that of sodium is represented by 30: the former, therefore, is a more powerful electric body.

The tetrædron (Fig. 2.) is incapable of entertaining the two electricities in a symmetrical manner, and is wholly passive as to either. It therefore depends for its electric state upon induction, and will be positive or negative, according to the state of the body within whose sphere of action it exists. Some other bodies, again, are almost altogether unipolar, as, for instance, the prismatic frustum, terminated by the negative pyramids (Fig. 8.). The electric state of such a form must be almost wholly negative.

18. *The pyramidal (positive) and prismatic (negative) polarities, may sometimes be so far displaced, even in a large mass, that one or other may be developed in excess, in a cer-*

tain region, and, of course, the consecutive one in excess in the consecutive region; and by being introduced into such regions, weaker bodies may be rendered more or less unipolar, or their natural state be more or less changed for a longer or shorter time. Suppose we are in possession of two such bodies as a magnet and a bit of iron. In the latter, when its magnetic equilibrium is not disturbed by induction or rotation, the contiguous particles neutralize each other's polarity, and the whole mass remains quiescent. No free polarity is therefore exhibited; but let one pole of the magnet, as, for instance, the northverse, be brought near the bit of iron, the subtile matter of this pole of the magnet draws up the consecutive matter in the iron formerly in quiescent union with the other, and, at the same time, depresses that other, because both are elastic or impenetrable to each other. Thus a state of polarity is *induced* upon the iron by the proximity of the polarity of the magnet, the order of the poles always being such, that consecutive poles are contiguous. When the molecules of iron are, to a certain extent, insulated from each other by a certain crystalline state, or admixture of carbon, oxygen, sulphur, phosphorus, &c., the polarity of the mass once induced, may be sustained in a state of free development for an indefinite time, if not altered by a subsequent induction, heat, a rapidly vibratory motion, or like accident. The mass becomes, as it were, one molecule, and it will be afterwards shewn, that a particle of iron is destitute of an axis, or any feature that should give a direction to its polarity naturally one way more than another. Hence, in such a mass, poles may be induced in any positions to which the external form is suitable. It is only the angles of the superficial strata of particles, however, that can be induced into this state of unnatural constraint. In the interior of the mass, the consecutive polarities continue to neutralize each other; and as much free polarity may be induced upon a hollow as upon a solid mass, provided the thickness of the walls do not fall below a certain quantity bearing a relation to the extent of the surface.

Again, let two disks of dissimilar substances (that is substances of dissimilar forms, and, consequently, dissimilar electrical states) be taken and brought near each other; each will disturb the electrical equilibrium of the other, a mutual decomposition of their electricities will ensue, and each will become polarised—those aspects fronting each other being expressive of the relative electrical states of the two bodies. Let N (Fig. 16) be a thin disk, capable of becoming polarized, but not in this state when insulated, and negative in relation to the disk P. When they are brought near each other, the equatorial (negative) fluid of N draws up the pyramidal (positive) fluid of P, coming out at the same time to meet it, while both re-act in pushing before them, towards the most distant or external surfaces, or even expelling a portion of the polarities of nonconsecutive kinds respectively; hence, each of the two disks is in a polarized state by induction; and two polarised axes are developed, one in each thin plate. But when they are brought into perfect contact, the two axes must be confluent into one, and the poles reversed. The disks become one mass, which is (though not more eminently than previous to justa-position, nor perhaps even so much so) positive and negative, on opposite aspects, according as one or other is most proper to the substance of that surface, and the region of union is neutral, being the neutral plane of an axis. On separating them after contact, the disk N consequently contains neutral subtile matter + negative, and is therefore negative; the disk P contains neutral matter + positive, and is consequently positive—the state of coercion existing for a longer or shorter time, for minutes, hours, or days, according to circumstances. The re-union of the neutral and the pure positive or negative states re-establishes the original condition.

To develope these phenomena in a symmetrical manner, it is necessary that the quantity of electricity in both disks be the same, and the one as far from a perfect neutrality, by excess of positive electricity, as the other is by excess of negative. Hence it follows, that there is a certain relative magnitude between particles when their union, in consequence of difference in electrical state, takes place with most effect. Thus, perhaps, the triangular bipyramid (Fig. 8.) is much more highly positive than the compound form (Fig. 15.) is negative; and the intensity of the one is just neutralized by the quantity of the other, so that a vigorous union may take place between them, and the compound particle resulting (Fig. 17.) be destitute of the properties of both, and exhibit only that which is proper to its own form, considered as one. Hence the electrical power of a particle is expressed by

quantity × *its intensity*.

In experiments on compound masses, whose polarity is excited by artificial means, the phenomena of induction make the same power act the part both of attraction and repulsion. Thus, light bodies, not charged with the same electricity, are attracted to such as are charged, and a similar polarity being induced upon them by their vicinity, or contact, they are then repelled, because there remains no force to retain them united; but when one particle is drawn to another, in virtue of a dissimilar electric state, they are attached by the attractions of their angles; and even though a similar electric state be induced, there is no departure; hence a molecule does not throw off spontaneously those parts which are in the same electric state. For, relieving it of such parts, it is necessary to make it hot, which weakens the intensity of the cohering force, and strengthens the existing electric repulsion at the same time.

Dissimilarity of substance is not necessary, however, to the development of a polarized electric axis. Dissimilarity of state in the same sort of substance, in different regions, produces the same effect. It is, in fact, equivalent to a dissimilarity of substance. Many bodies, when in the aëriform, liquid, or red hot state, are more different from themselves when solid and cold, than they are, in either state, from many other bodies. Hence, if on one extremity or aspect a body is heated, or is passing off as a liquid or a gas, the mass will be (within the limits of distance always to be considered) in the state of a polarized axis; and in such cases, it is to be observed that the region of activity is naturally the positive pole. Thus, let a bit of charcoal, burning at one end, be held so that the fumes passing off from the burning part shall not interfere with it, and it will be found that the hot end is positive, the cold end negative. Again, let it be held so that the fumes, as they pass off, may sweep along the surface of the mass; charged, as they are, with the positive fluid, they give it off to that region which would otherwise be negative, restore the equilibrium, and prevent the development of an axis. These facts, though explained in a different manner, have lately been observed by M. Pouillet. The same phenomena are beautifully exhibited in flames, as will afterwards be shewn.

This motility of subtile matter induces us to believe that the quantity investing any given particle is not invariably the same, but becomes excessive or exhausted, more or less, according to the phases through which the body has lately passed. It is most reasonable to believe, that, in certain cases of contact, or union, the electrical state of a body is so far affected, that, when it is set free, its condition as to subtile matter is not the same as it was previous to contact; and that it will require exposure to some bodies having abundance or deficiency of subtile matter, a relatively positive or negative state, to restore it speedily to that proper to its form. Many electrical experiments are most easily explained, on the supposition that there is an actual transference of the subtile principle; and it seems very credible that in many cases it is so. The grand means of restoring subtile matter to a body which has been deprived of it, is exposure to the sunbeam, which is not to be wondered at, when we consider its structure, afterwards to be described.

All substances are not capable of developing polarized axes. This is true, however, of most bodies in a somewhat neutral and natural state, in which they are, of course, well served with both fluids. Other substances, as many of the undecompounded bodies of metallic lustre, are much more remarkable for the ease with which they conduct and circulate the polarized state. This peculiarity depends on the mode of the aggregation of their particles, as well as on the fact that they are not in a natural state; for it has been remarked of several substances, that they are conductors or electrics, according to their density. There is reason to suspect, however, that the conducting powers of the same metal or solution, would be different for different sorts of electricity. Thus, one result would be obtained when hydro-electricity was transmitted, and another when vitreous or resinous electricity was transmitted. Water is a very bad conductor of its own electricity, as might be expected, becoming polarized in the region contiguous to the excited body; hence a galvanic spark may be obtained in water. But it conducts vitreous and resinous electricity better, or is more passive to them, serving merely as common matter in aiding to establish an equilibrium. Perhaps the phenomena of conduction are merely a modification of those of induction, in which there is nothing to limit the length of the axis; and in which the conducting tissue serves merely as a medium of common matter for transmitting the polarity between bodies in dissimilar states. To such a transmission, the interposition of laminæ of subtile matter having an individuality of its own, and capable of being excited into a polarized state, opposes a barrier. Hence crystals, whose molecules have a specific polarity, and rare bodies of a symmetrical structure generally, are bad conductors of electricity. Dense bodies, again, with faces pressed against each other, in which there is a continuous tissue of atomic matter from one end to the other, transmit the subtile principle with greater ease.

Let AX (Fig. 18.) be a filament composed of tetraedral, icosaedral, or any tessular or spheroidal particles or molecules, whose motorial fluid depends on induction or position for its polarity; and let the molecules of which the filament consists, in consequence of a mutual repulsion arising from similarity of nature, be free to move so that their centres shall remove from each other to a certain distance, and yet the filament be preserved. Each molecule will be polarized by induction, that in the centre being neutral; and were the mutual repulsion presently existing anyhow conducted away, the whole series would contract towards the centre or neutral point, for the consecutive poles of the molecules must be contiguous, and whatever phase one extremity took on, the same would be induced upon the other.

The action congenial to its structure of a hollow body (consisting of such filaments), whose form is cordate, or an equator with a pyramid only on one side, is to move so as to dispose of matter thrown into its interior on the other side of the equator, and thus to evolve a bipyramidal or symmetrical form, or one of repose. Action tending towards the same object, will, moreover, be aided by a structure in which the matter may be thrown between parts which are of unequal magnitude, in which case, it will always be from the larger towards the smaller, both tending by alternate contraction and expansion to establish equality and symmetry between them, at which æra the mass becomes inert.

If a polarized axis be supplied with other molecules at the neutral region (where they may lie in any positions demanded by their forms, without regard to symmetry), they will be carried towards the extremities with a force proportional to the vigour of the system previously constituted. Changes in the vigour of the system will not much affect the neutral region. The same quantity of molecules, then, continuing to be added there, when the force to remove them towards the extremities of the axis is abated, they will be arrested in their departure near the neutral region, and, instead of being attenuated and lengthened, the form will become incrassated. In a state of repose, a flexible axis will naturally be bent into a circle. These laws are illustrated in the contraction and structure of muscles, the movements of the heart, the changes of forms which the trunks of animals undergo in mature age, and the positions in which animals having long bodies sleep and hybernate. But this subject will occupy us in the Fourth Book.

19. *Subtile matter is so modified by the form which it invests, that when the electric state of two dissimilar bodies is the same, or nearly so, the subtile matter of the one does not attract or repel the other in the direction of their centres.* In reference to gaseous bodies, this property has been detected by the genius of Dalton; but it is one of universal extent, and intimately connected with the permanency of natural species. There is, indeed, an universal attraction, and an universal repulsion, of a certain extent, between all bodies, because all bodies are ultimately similar, being formed of similar atoms; but the sphere of this action is very limited (the quantity of matter being the same), compared with those attractions and repulsions which subsist between bodies of the same, or nearly the same, species. Were there an universal alloying, mingling, repelling, attracting, among all substances, creation would only be in repose when it was the most perfect chaos. The individuality of species would be lost, and, like substances in a laboratory, all the beautiful things of nature would require to be kept in phials, made of mere space, and placed at a distance from each other; or else, like hawks and pigeons, they must needs be endowed with life, instincts, eyes, and wings. But as it is, a specific substance, when it cannot improve its electrical state, and, consequently, approximate the form of its particles to the spherical, does not either attract or repel from itself other species around it, unless they be so exceedingly near it, that their specific difference is overcome by their generic identity. Each rises in vapour at its own time, crystallizes according to its own fashion, or keeps off others of its own species, when aggregation is forbid by the excess of the repulsion above the attractive energy between them. The subtile matter of the magnet finds no obstruction from a plate

glass, wood, or lead, and these bodies suffer no change by permitting the subtile influence to pass through them. Nay, one's face may be made to touch a most vigorous magnet, and a needle may be violently agitated at the back of the head, by the transmitted influence, without either the head or the heart being in any degree affected by such osculation and transmission of the subtile principle. If nickel and cobalt recognize the magnetism of iron, and are really magnetic in a similar manner, it is to be inferred that some considerable part of their form is isamorphous with iron. As to that very general attraction of small bodies, exercised by the magnet, in as far as it is purely an attraction, arising solely from the influence proper to the angles of particles, it seems to arise from the iron which they contain; for where is there a body that may not contain iron? And, as to those south and north magnetic poles which are found at the summit and base of most bodies, the iron, in their composition, may be the means of enabling us to recognise such an interesting fact, becoming thus, by its universal diffusion, to the magnet, in reference to the attractive influence, what light is to the eye in reference to the repulsive, but it is not to be inferred that the iron in them alone possesses these polarities. This mutual disregard, however, bears in its quantity a certain relation to the quantity of difference between the dissimilar bodies; and it may be that there is scarcely any form in nature that might not acknowledge the influence of a vigorous magnet, by attractions and repulsions. As to rotation, it is probably the effect of the re-action of the subtile matter of dissimilar bodies, though much more eminently in those which are most nearly allied. Thus the electricity of other metallic bodies, (such as copper), which are nearly allied to iron, produces electro-magnetic phenomena much more eminently than the electricities of vitreous and resinous substances.

This specific modification of the subtile principle, is productive of many most interesting phenomena in the laboratory, as well as in nature. Thus, when a volume of pure water is charged with a quantity of a certain salt, in solution, so that it cannot accommodate any more of that sort, it may yet receive an additional quantity of another, depending upon their analogy and the relative solubilities of the two salts. The two salts are constituted in the water, as two gases are in the radiant matter; the particles of each sort are equidistant, and symmetrically arranged, and the one system may suffer union, or precipitation, while the other is but little affected. Again, two liquids may be mingled, or two solids compounded, and each may be driven off at its own temperature, or congealed, or otherwise changed, without interfering with the other, except, perhaps, in as far as a cohesion may have accidentally taken place among a few particles. The phenomena presented by the gases, however, are most interesting.

The aëriform state differs from the crystalline and liquid, when the aëriform body is uncompressed or in a state of repose, only in its rarity. Doubtless the particles do not roll about, and present their aspects to each other by chance. Though their mutual repulsion preserves a considerable sphere of subtile matter between their solid nuclei, yet there is no reason to doubt that an influence adequate to maintain a symmetrical relationship of the particles to each other, extends through this repulsive medium; and that the particles are all of them in fixed positions, and the whole volume a symmetrical tissue. The strength of the symmetry of this tissue, will obviously depend upon the smallness of the number of directions in which the particles are bound in their positions of symmetry. Thus every tetrædron (Fig. 2.) is bound by four angles only, and before it could roll or rotate amongst its fellows, any angle would require to move through more than 30° at least, to which movement every thing would be opposed. Two of the pentagonal bipyramids again, (Fig. 4.), might react upon each other very symmetrically, and the whole rotate, like toothed wheels, the contiguous laminæ in opposite directions.

Upon a gas thus constituted, then, another may be let in, and if they be very dissimilar in nature, it will be equally diffused, almost immediately, and will constitute its own symmetrical tissue, without interfering with that of the other, provided there be not a strong chemical affinity between them, or one or other, or both, impatient of the gaseous state. The only phenomenon which ensues, is an expansion of volume, equal to that of the gas added, because the quantity of elastic matter in the gross is increased to this amount; and doubtless, the water or mercury, which limits the volume, is pressed down by the one elastic thing as well as the other, or in a similar manner as if the same number of homogeneous elastic particles pressed upon it as are involved in the mixed volume. Gases, in this state of mixed volume, are, however, in a very critical condition, provided their forms are harmonious, and their electric states not nearly approaching to similarity. For, let the symmetry of the volume be shattered by an electric discharge, or let the tendency to the evolution of more quiescent forms be stimulated by exposure to the sunbeam, or fire, and they will unite, and, having united chemically, cohere crystallographically, or in virtue of the attractive energy.

The difference between a vapour and a permanent gas, arises from the relative extent of their repulsive and attractive energies, which are affected inversely by heat. While they are kept beyond their spheres of cohering energy, or while these are, as it were, surmounted and locked up by the repulsive energy, they remain aëriform; but when, by a depression of temperature, by compression, or otherwise, the influence of the attractive energy becomes greatest, they instantly collapse, like the index of the magnetometer formerly alluded to, and the body becomes a liquid or solid, according as its form is most suitable to one or other.

But though this consolidation of matter into more highly concrete forms be exhibited in many phenomena, it is the nature or function of subtile matter universally, upon the whole, to expand the volume of the atomic matter with which it is mingled, the repulsive influence being more powerful than that of cohesion. Hence there is a mutual penetration and interlacement of dissimilar bodies. Every volume of a liquid has an atmosphere of its vapour over it, of a density depending on its nature; and every aëriform body penetrates, in greater or less quantities, into the liquid or other penetrable or porous bodies beneath it. It is most curious to remark how the same circumstance which permits of the interlacement, also sustains the vapour in that state. It seems, at first sight, very strange, that, when water can absorb a large quantity of oxygen, and many other dry gases, it should permit an atmosphere of its own vapour to stand over it, of considerable density, though aqueous vapour settle fast upon most bodies, and it require a strong heat to change water into steam. But oxygen gas is a dissimilar body to water. Its particles are not repelled by those of water. Pressed by its own volume from above, it filters through the superficial laminæ of the water, and lodges there, in a quantity proportional to the force by which it is squeezed in. Vapour, again, is a similar substance: the lowermost laminæ of particles of vapour are recognized, repelled, and kept off by the water, their heat being that of steam, and their repulsive sphere extending beyond their attractive; and this inferior lamina of steam sustains the weight of all above it. But if the medium which is to absorb it, be changed, and oil of vitriol, or a dry porous body, be substituted, then water shews that it is impatient of the aëriform state. In like manner, if any gas be exposed to a porous substance, such as a bit of fresh charcoal, the particles are not repelled from it. The gaseous particles press those beneath them into the pores of the ligneous tissue, and such volumes as are impatient of the gaseous state, settle in considerable quantities, as liquids, and remain condensed, so long as the pressure of their particles remains upon them. But when the ambient medium is changed, that is, when they are relieved from the pressure which forced them down, they ascend again, and interlace the new atmosphere, which does not oppress them.

20. *The subtile matter investing a body acquires more and more of a repulsive action, as the rapid vibratory motion or heat of the particles affected becomes greater, the attractive energy arising from the angles diminishing at the same time.*

It has been already stated, that the attractive energy of particles is diminished by heat, and such motion as is produced by friction or percussion rapidly repeated. The same modes of action impart energy to the repulsive principle, and the simplest view which can be taken of the case, is to suppose that these are two factors, varying inversely as each other, the one gaining in every case what is lost by the other. It is entertaining enough to believe that the subtile matter, by a very rapid vibration of the angles, is displaced from them, and resorts, in a concentrated state, to the surfaces, the regions of greatest repose. But, resident there, it produces the phenomena of repulsion, and thus it passes from the character of the power of aggregation to that of chemical union. When the form, again, becomes quiescent, its former condition is restored. The action of heat in producing new substances is thus doubly effective, for, first, it diminishes the unity or cohesion of those now existing; secondly, it exalts the electric state of the bodies considered, and, consequently, makes the quantity of dissimilarity in electric character to be greater, in virtue of which they are enabled to unite; but having united, the sustained electric state would be of no use, as they cohere in virtue of the attractions on their angles; for this attraction, though weakened for the purpose of producing that state of things which could alone give rise to union, recovers strength as the unnatural electric excitement subsides with the temperature, and thus the particles, when cold, are left in a state of strong cohesion. Friction is very often resorted to as a means of developing electricity, but this is probably in consequence of the great heat which is induced upon the superficial particles. We have, certainly, no means of detecting such heat, though it existed; and, since we find that a mass soon becomes sensibly warm, when rubbed for a short time, the heat of the superficial lamina must certainly be excited as soon as its electricity. But, perhaps, a ruder tremor than that of heat may be adequate to produce the same effect.

All things considered, and without pretending to be very confident as to a mechanism, of which ocular demonstration cannot be obtained, the following may be regarded as the distribution of the subtile matter around a molecule, or pile of molecules, or particles, whose form is not spheroidal and quiescent. Let AX, EQ, (Figs. 19. and 20.), be the axis and equator of two forms, in a plane parallel to the axis. When these are not equal to each other, the molecule is not quiescent. When the equatorial diameter is shorter, as in Fig. 20, the form is electro-positive. When it is longer, as in Fig. 19, the form is electro-negative. Each is invested by a specific quantity of subtile matter, derived from the ultimate atoms of which it consists; and this subtile matter possesses unity and sympathy of parts, even though the external form of the pile of molecules, as a bit of glass, may be destitute of specific form. The subtile matter in each hemisphere of the polarized molecule, may be regarded as in a state of circulation, the external current being in electro-negative forms, such as (Fig. 19.) from the equator towards the poles; in electro-positive forms, such as (Fig. 20.) from the poles to the equator. Thus, in each side of the equator, there is supposed to be a vortex of subtile matter, from which the axis and equator of the molecule are excluded. It follows, therefore, that in some position depending on the form of the molecule, and in the region which is the physical centre of each of these circulations, there must be in both hemispheres an annulus of subtile matter, which does not partake of the same motion as the surrounding parts, but is the circular axis, around which the vortex revolves. This circular cylinder, or annulus, is therefore free to move otherwise, in obedience to the laws of subtile matter. Since, then, the subtile principle, constituting these annuli, cannot move in the same direction as the other parts, it must move in a direction at right angles to it, and thus it becomes related to the first, as magnetism is to electricity, though these terms, leading us to think of matter in very peculiar states of polarity, are rather apt to derange our general views. The direction of the circulation in these annuli, parallel to the equator, depends upon the direction of the vortex in the plane of the axis, and *vice versa*. It is opposite, according as the form is electro-positive or electro-negative. And this is to be observed, that, whatever be its direction in one hemisphere, while the circulation goes on between the poles and equator, it must have an opposite course in the other hemisphere. It follows, therefore, that the polarity of these two annuli, on opposite sides of the equator, is in consecutive states, for this is always implied by opposite currents in a parallel position. If we suppose, then, that the subtile currents have greatest energy at the poles in the electro-positive molecule, and at the equator in the electro-negative, it follows from the discoveries of Ampere, as to the repulsion exerted between two currents, thus related to each other, that the action resulting from these currents upon each other, is to dilate the polar region in the electro-positive molecule, and the equatorial region in the electro-negative, which must conspire with other causes to evolve the spheroidal form.

There are, then, in a polarized molecule, two sets of polarized axes. One set, analogous to the terminal edges, whose poles are contiguous to the extremities of the axis and the equator of the form, and which possess similar poles at both extremities of the axis, and poles consecutive to these, and similar to each other at the equator; the other set, having their consecutive poles in opposite hemispheres, the neutral point being the centre of the molecule, and the poles applied to the neutral regions of the first set. The limit of the polarized action is, when these two sets of axes are applied to each other at right angles, in which case, the polarized axes extending between the poles and equator, are represented in any plane passing through the axis by the sides of a square, to which the other set of axes are perpendiculars raised from the middle of the sides, and the axis and equator of the molecule are diagonals. The limit in which this state of things can be attained, is when the molecule is a sphere, or a tessular form inscribed in it; and hence it is that the polarized action demands the evolution of a spheroidal or tessular form, as perfect as the angular shape of the molecules will admit. To distinguish these different planes and lines, which must obviously possess very different properties, —as the lines A X and E Q lie between the polarized regions, and are equally affected by both, we may adopt the name of neutral axis, already applied to lines possessing similar properties, and not differing from those now considered. The oblique axes, of which the annuli parallel to the equator are the poles, and whose neutral region is the centre of the molecule, may be called polarizing axes. (It is obviously the same power which polarizes and which depolarizes.) The third series of parts, including the axes corresponding to the terminal edges, may be called the terminal or meridional axes.

When the spheroidal form has been attained, which it thus becomes the limit of polarized action to evolve, the terminal circulation becomes quiescent. The cause which made the annuli parallel to the equator to move in opposite directions is of course removed, and their consecutive state is consequently obliterated. Thus, the abolition of the terminal axes or vortices involves the abolition of the polarizing axes; for a polarized axis implies consecutive poles at its opposite extremities. The subtile matter now remains without any determination between the poles and the equator; and, were the molecule absolutely cold and insulated in space, its subtile matter would be wholly in a state of repose. Every molecule, however, as a member of the universe, has a certain quantity of heat, which, as will afterwards be shewn, cannot be equal in degree in every part of the molecule; and it is also surrounded by the subtile matter of other bodies, and exists in it. Hence, if the subtile matter of these other bodies be in a state of polarized action, it will induce motion, at right angles to itself, in a quiescent molecule exposed to its action; and as there is nothing in the quiescent molecule itself to subdivide this induced circulation into opposite currents, it will move in a mass. Therefore, the molecule, whose polarity is quiescent, must rotate among the others as often as it is able to overcome the mechanical obstacles in the way of a free movement. Now, in every case, where the circumstances are such as to admit of this rotation of spheroidal molecules, it has been observed. Water is a medium of a very fluid nature, and many molecular bodies are of the same specific gravity with it; water, therefore, serves as a medium for suspending molecules, and relieving them from the fixture of position arising from their gravitation. When a molecular body is broken down, then, such of the molecules as escape in the entire and spheroidal state, when of a dissimilar nature from the water, so as to escape attractions and repulsions, ought to rotate in that medium; and that they really do so, is most amply proved by microscopic observations, especially those of Muller and Brown, who, above all others devoted to such observations, it is difficult to deceive. The latter, in particular, has shewn us that spheroidal molecules, from whatever body derived, from the pollen of a plant or the granite of the Sphinx of Egypt, rotate in water. Organic molecules such as those of the pollen of plants, are large enough to be easily visible during their rotations; and, if the particle of pollen be destroyed in an immature state, the molecules and particles will be seen to produce shooting, digitated, and arborescent forms, which, in that condition, it is the province of rotating molecules to develope. When a vegetable infusion has been permitted to stand for some time, though it may have been boiled, and the vessel containing it hermetically sealed while full of steam, rotating molecules of a pellucid nature appear in vast numbers, which are easily to be observed. Their rotation necessarily implies an occasional and desultory progression, in consequence of the partial and unequal resistance of the medium in which they move; and, in certain positions, they seem to become polarized, for they become fixed in position, and currents are observed flowing towards a pole. On a sudden, this motion becomes reversed, or is brought to rest, and the molecule rotates, and proceeds gyrating, ascending or descending, as its subtile matter demands. Such bodies are commonly regarded as animals, and, if they be gelatinous, most probably they are; but, according to the views of the animal nature, noticed afterwards, they could not, in as far as observation is only made of their motion, be regarded as animals. Some seem more analogous to ova, destitute of an embryo, and, consequently, of the power of evolution. The movements of the ova of Sponges, Alcyonia, Sertulariæ, and other analogous tribes, as has been amply shewn by Professor Grant, are highly analogous; but they are provided with saliant radii, which the others want. Their form, as far as I have observed, is never spherical or symmetrical on opposite sides on the equator. After their free movement, which is produced by the rapid movement of the cilia, has continued for some time, it languishes, and ultimately ceases, the ovum becoming diffuse shortly after, and expanding into an attached disk, containing the embryo of the species from which the ovum proceeded, and out of which the organized form is developed. The ability to bring itself to rest, independently of mechanical change, in the condition of its matter, or the subtile state of the surrounding medium, rather than that spontaneous movement which we erroneously regard as the result of sensibility, is the characteristic, in as far as obvious motion is concerned, of an animal nature.

It appears, then, that the first fit of polarized action, is to develope, out of highly angular atoms, which, taken individually, are passive as to polarity, spheroidal particles, which, also taken individually, are passive as to polarity. The angular particles, during the different stages of their increment, give rise to solid and *frangible* crystalline bodies. The spheroidal molecules are fit for constituting the solid and *flexible* parts of organic bodies. Like ultimate atoms, they depend for their action on their position; and the movements of atomic masses, to which they give rise, are regulated by the same laws.

21. *Subtile matter, investing a specific form, exerts a certain influence on the surrounding subtile matter, to reduce it to the same state with itself.* It seems very credible, that the subtile matter investing a well organized particle of matter, or group of particles, should assimilate to its own state the contiguous subtile matter more deficient in individuality and specific character. This assimilation, however, must obviously, except in cases where the contiguous subtile matter is nearly the same already, be a very slow process, for it can only be permanently affected by the surrounding atomic matter being induced by its subtile matter into the same form. The obvious consequence, then, of this reaction, were there such, would be the development of natural bodies in groups; and the law expressed amounts to this, that every permanent body exerts a certain influence on the surrounding matter to repeat its own form in it: and hence quantity comes to be a consideration of vast importance in chemical philosophy. A large quantity will resist a change to which a small quantity might be necessitated to yield; and after a change of form has begun to take place, it will go on in a geometrical progression, the increased quantity that has been changed constantly exerting an increased influence to change the remainder. Of the evidence for such an influence, nature and the laboratory are full. It is merely a modification of induction, a principle of vast extent. Thus, let us take a solution saturated with saline matter. Provided there is no concen-

tration or loss of heat, it will remain a liquid for any length of time; but let a crystal, or, still more, several crystals of the substance dissolved, be introduced, and in a short time hundreds of little solids, like those put in, everywhere make their appearance. If, in the same way, any angular solid be introduced into a saline solution, though not with the same effect, yet it disposes to the evolution of other angular solids, which in this case can be nothing else than crystals. Occasion will often be taken afterwards to recur to experiments, where the same principle manifests its energy. In the phenomena of nature, it is everywhere indicated. Thus, every species has its locality. Where one crystal is found in a rock, there are usually more than one. One or several crystals for instance, are developed in a rock, otherwise in a mechanical or constrained state: if the matter of the rock be already nearly in a similar state with the crystals, the atomic movements (towards which, what we call solidity, can scarcely be an impediment) are all towards the development of other crystals of a similar form with those already developed, provided there be no modification to produce a resultant force, and an intermediate species. The rock thus becomes porphyritic and ultimately granular, and all its cavities become drusy, with crystals of a quality bearing a certain relation to the matrix out of which they have grown. If there be any justice in the views of matter advanced in this work, the crystalline only is the quiescent state of inorganic matter. Every muddy and mechanical mass is in a state of constraint, with faces applied to angles and edges to faces, equators to equators, and poles to poles, every thing accidental, repulsive, and wrong. But the ultimate atoms are all uninjured, and there are many little crystalline particles and fibres left undestroyed, to serve as ferments and embryos for a new development of beauty, symmetry, and quiescence. Accordingly, nothing but time is necessary to change the muddy and mechanical stratum into a crystalline rock, which, through the influence of the contiguous strata, will probably be on their confines changed into their substance, though the matter of the rock forming, taken by itself, be disposed to constitute another substance. Thus, a stratum may pass into the adjacent rock without being contemporaneous, and become crystalline, without the aid of fire or water. Fusion and solution will no doubt aid very powerfully, by permitting the particles to assume at once their positions of quiescence. But, when we consider the incalculable force of the attractions on the angles of atoms,—when we consider that the particles of an iron wire, not seven hundredths of an inch in diameter, will support a weight of nearly a quarter of a ton, rather than let go the hold which they have of each other, in virtue of their mutual attractions,—we will be diffident in assuming any supernal pressure or state of hardness so great as to oppose the movements of constrained particles towards their symmetrical, their crystalline, their quiescent positions. These views might be illustrated at great length by evidence drawn from geological phenomena, from the efflorescence of crystals, and the change of position in the particles of hard crystalline bodies, as indicated by a change in their axes of polarization. But this could not be done with any advantage in the present state of our inquiries. I shall therefore only remark farther, that the action of subtile matter which has now been stated, is the most important of all the laws of Nature. It may be called THE GRAND LAW OF IMITATION. Amid the almost infinite variety of forms of which matter is capable, this law prevents the development of all strange and incongruous substances, and demands that every thing subsequent shall be in harmony with what is before. Moreover, it implies that the atomic action of the universe tends constantly towards a crisis. For the result of imitation is assimilation, and the result of assimilation is quiescence.

OF HEAT.

For explaining the phenomena of heat, or that which causes bodies to become rare, luminous, and feel hot, another kind of subtile matter has often been assumed. Some philosophers have even not scrupled to ascribe an atomic constitution to heat, deeming that the expansion to which an increase of temperature gives birth, might be accounted for by the infiltration of the particles of caloric from the source of heat into the body warmed. Others have inquired whether heat was a thing that could be weighed in a balance. The fact, that heat may be obtained in an inexhaustible quantity from a very small fibre of platina-wire, which may be kept red-hot in the voltaic focus for any length of time, and that an indefinite quantity may be elicited by friction from the same materials, render this opinion of the materiality of heat untenable. Heat also differs from subtile matter in all its affections. It is not polarized. It does not give rise to attractions or rotations, except in so far as it may exhilarate these motions proper to subtile matter; and it differs entirely in the mode of its propagation, being transmitted through the best solid conductors only with extreme slowness, falling off in intensity from the source of heat to the other extremity in a geometrical progression.

There is no reason to doubt that heat consists in a tremulous motion in the atoms of bodies. It has been shewn that such a motion weakens attractive energy, and increases repulsive. Hence, when a body is heated it expands, both because the cohesion of its particles is diminished by the tremulous motion of the angles whence the forces of cohesion emanate, and because the elastic matter resident in the faces of the particles increases in intensity, and demands a greater volume. Rarefaction, then, an exhilaration of electric state, and a more feeble cohesion, are the necessary consequences of an increase of heat; and these are well known to be the phenomena which a rise of temperature produces.

The number of causes which tend to expand a solid or liquid body, is different from that which tends to expand an aëriform one. In solids and liquids, there is an actual calorific repercussion, causing the particles to start away, according to the ordinary phenomena of elastic impact; there is also a diminution of cohering energy; and, further, there is an increase of elastic force in the subtile matter. In aëriform bodies, on the other hand, the particles are insulated from each other, and there can be no actual impact or atomic recoil; neither can there be any diminution of cohesion, for the particles of gases are already free from the restraint of cohesion, and their attractive energy only remains as a directive force to sustain symmetry. There is imparted to them, then, by an increase of heat, only an increase of elastic force, or capacity to occupy the same volume with a greater pressure upon them; and the law wich determines their volume, as modified by temperature, ought to be sensibly the same as that which determines it, as modified by pressure. The expansions of solid and liquid bodies ought to be in a higher ratio. Now, it has been fully ascertained, that, in as far as can be observed by the eye, the movements of gases from change of temperature are perfectly analogous to those induced by change of pressure; and the amount of the heat, by which a gas is expanded, would be indicated, either by noting the amount of the expansion, or the weight required to compress it to its former bulk. The expansion is in both cases proportional to the weight which the gas sustains. It has also been ascertained of solids and liquids, on the other hand, that, while the increments of temperature, as measured by an air thermometer, are in arithmetical progression, their corresponding expansions are in geometrical progression.

The modes in which heat is excited, also indicate that it is motion. Thus, when a body which does not relieve itself by breaking in pieces is struck, and its ultimate parts made to move among themselves, it becomes hot. The concussion not only excites the elasticity of the mass, if the mass chance to be elastic, but it trills through the ultimate atoms, which are always elastic, and are broken off from their positions of cohesion, and thrown into a state of vibration, or, in other words, the body struck is warmed. That series of concussions rapidly consequent on each other, commonly named Friction, is also a powerful means of exciting heat; and it is well known, that, without in any degree changing the nature of the body on which the attrition takes place, any quantity of heat may be excited in it. It is commonly said that heat may be excited in six different ways,—by the sun, by combustion, by chemical action, by mechanical action, by electricity, and by life. In all these cases, however, heat is excited in one of two ways,—either the two parts of the atomic matter of two bodies directly act upon each other, and that which has the greatest quantity of motion transfers it to that which has less, till the quantity is equalized between them, according to their several capacities for entertaining a state of tremor; or the atomic matter has the motion communicated to it through the medium of the subtile matter which invests both, as in the case of aëriform and rare bodies.

From the fact that the attractive energy is weakened during a state of heat, a very important consequence follows, viz. that the same quantity of matter in a hot state is lighter than when in a cold state; for the weight of a body depends upon, and is entirely caused by, the amount of its attractive movements towards the earth. The experiments of De Luc, Fordyce, Morveau, and Chaucier, all lead to the conclusion here stated as necessary; but it seems extremely difficult to perform decisive experiments on such a subject. Besides, all the amount of change in the vibrations of bodies between the greatest colds and greatest heats we can command, may probably be very inconsiderable, compared with the difference of vibration in different bodies, expressed by their specific heats. Every circumstance in the experiments also tends to introduce a double error, which works both ways to equalize the indications. If water changed its capacity for heat as much in passing from the liquid to the solid state, as it does in passing from the liquid to the aëriform, a bit of ice, and the same quantity of matter as water, ought to have a sensible difference in weight. Could volumes of aëriform bodies be weighed with precision, the same matter in the solid and gaseous state would frequently, when there was a considerable change of specific heat, be considerably different. But it is difficult to suggest an experiment altogether free from objection. It is interesting to observe, however, that, when seeking for an increase of weight, accurate experimentalists have most frequently found a loss, and never an accession.

27. One is again tempted with a speculative question analogous to the infinite divisibility of matter, or the conduct of a body in vacuo—is a state of stillness or absolute coldness, or a state of tremor or warmth, most congenial to the constitution of atomic matter? We shall infer that the latter is most congenial, because all bodies are more or less warm. Nevertheless, as far as observation can carry us, we conclude, that atomic matter is perfectly inert and passive. If it has never been warmed from without, it remains perfectly still and cold; and when it has been warmed, it cannot bring itself to rest otherwise than by parting with its calorific excitement to contiguous bodies, or by the re-action of different regions of its own form, neutralizing the action of others, and rendering a state of greater coldness alone compatible with the mechanism of its constitution.

28. From the fact, that the units, or ultimate atoms, of all bodies are the same, and that these atoms are, in different bodies, differently built and deposited, some with their angles

more free, some with their angles more restrained, it follows that the particles of different sorts of bodies shall have different capacities for heat. Some may be compatible with a highly vibratory state, while others, in the same external heat, may be necessitated to remain comparatively cold or at rest. Thus, comparing together the several forms which have been already frequently attended to, we should infer that the tetraedron, (Fig. 2.), from its very acutely angular structure, would be capable of being excited into a state of most intense heat; but that, when surrounded with other bodies, it would not naturally sustain a high calorific state, for there is no symmetrical exposition of the vibrating parts, and a tremor propagating from the centre is not symmetrically conducted on opposite sides. The triangular bipyramid, again, (Fig. 3.) is admirably fitted for sustaining a very strong state of heat. The capacity for heat of the pentagonal bipyramid (Fig. 4.) must be less, for the pungency of its polar angles, which only are opposite to each other, is less. Of those whose electrical relations were compared, the form (Fig. 13.) seems next well suited for vibration, for the whole being solid and symmetrical, the tremor may be propagated from the centre without interruption. Then follows the form (Fig. 15.); and then the binate molecule, (Fig. 14.), which, probably, has two points at zero analogous to the foci of an ellipsoid; and, last, is the frustular form, (Fig. 8.) which is equally destitute of vibratory angles and opposite parts. It is also to be remarked of this form, that the centre of elasticity, a point which, in every body, at every degree of temperature, must be absolutely cold, is exposed to the incidence of other bodies. Such bodies, then, could not be dislodged thence simply by the institution of a reverberatory action between them.

29. The susceptibilities of atoms for entertaining calorific tremor, will evidently be greater the farther they are from the maximum state of motion of which they are capable. Equal applications of heat, therefore, will not produce equal increments at different temperatures. A very cold body will become warm with avidity. One in a state of vibration greater

than that which is specific to it, supposing it to be cooled down from the maximum of which it is capable, will be farther heated with difficulty. Previous to the arrival at that point which implies injury and destruction, all pieces of natural mechanism are observed to suffer retardations, and to refuse to move with their usual facility. Hence we may be able to understand what is meant, when it is said that the capacity of a body for heat increases with its temperature: for it is to be remarked, that the word capacity, as commonly used, signifies both capacity and incapacity, and often indicates nothing more than that it is difficult to increase the temperature of the body which is said to have a great capacity.

The capacity of bodies for heat, in the sense used in this work, is indicated by their specific heats as members of the world, or exposed to a common temperature, and the calorific re-action of each other. Were a multitude of forms, each being one or other of the sorts that have been so frequently mentioned, brought to a state of absolute rest or coldness, and then mingled together in a warm place; supposing no chemical union nor solution took place between them, they would aggregate according to their species—each would form a volume, whose parts, viewed in relation to each other, were symmetrical; and each would possess a certain quantity of specific tremor, or heat, according as its form had a greater or less capacity for entertaining it. This, then, is the specific heat of the body, an element of vast interest, affecting all its functions. But how are we to ascertain the specific heats of different bodies? The states of tremor which they now possess are all equivalent to each other, and the result of a mutual reaction: let a thermometer then be plunged in one, it is brought to an equivalent state of tremor, rising or falling as the case may be; let another thermometer be introduced into another, it is also brought to an equivalent state of tremor; but the tremor of the two bodies having different capacities for heat, were equivalent to each other, so also, therefore, must be that of the thermometers, and in both the bodies, though one of them, if brought to rest, might prove to be so hot as to give rise to rays of fire around it, and the other almost cold, still the thermometers give indications of the same degree of heat.

30. The ability of two or more bodies to warm a third, is named their relative temperatures. It indicates their relative power of imparting calorific excitement, or their disposition to part with the heat which agitates them at that moment. Thus, suppose a volume of matter in the state of tetrædrons, (Fig. 2.) and another volume in the state of triangular bipyramids, (Fig. 3.) formed by the union of two of the former; and suppose, farther, that it is only necessary to regard the heat excited in the acute or triædral angles of both, and that there is an equal number of such angles in both volumes, then the temperature of the volume of tetrædrons will be the same as that of the bipyramids, at an era when the vibratory excursions of the angles of the tetrædrons are less than those of the bipyramids, because the latter having a greater capacity for heat, instead of giving it off to the contiguous body, will rather, after the impact, communicate the tremor backwards to their own centres again, which the tetrædrons cannot, in consequence of the greater effort required to do so, when the amount of vibration is the same in both. The temperatures of bodies, then, are the indices of their powers of heating other bodies colder than themselves, but give no intimations as to the quantity of heat resident in these bodies, or the quantity of vibration existing in their atoms at a given temperature. The conducting power of bodies in reference to heat, like their conducting powers in reference to electricity, depends very much on their state of density or rarifaction. Strata of subtile matter seem an almost perfect impediment to the transmission of electricity; and it demands double work before the mechanical agitation of heat can be communicated across such laminæ.

31. The quantity of heat, in a certain quantity of any body, depends upon the specific heat of its particles, and their

number in the volume considered. In equal weights of a number of dissimilar bodies, then, we may say,

$$\textit{Quantity of heat} = \frac{\textit{the specific heat}}{\textit{the atomic weight}}.$$

It is difficult to see how the quantity of heat in different bodies can be accurately discovered. The specific heats of equal volumes of the gases, given by M. M. Delaroche and Berard, when reduced to an equal number of particles, and divided by their atomic weights, give about—

Fixed Air, . . .	.86
Intoxicating Gas, . .	.92
Air, ...	1.
Vital Air, . . .	1.
Nitrogen, . . .	1.02
Carbonic Oxide, . .	1.04
Olefiant Gas, . .	1.33
Hydrogen, . . .	9.2

The difference here indicated, except in the case of hydrogen, is inconsiderable. It does not seem possible to discover the specific heat of the particles of a body experimentally; nevertheless, the approximations which have been obtained are of very great value. These present great differences, as related by different observers; but all agree in insulating hydrogen gas from all others, by a most remarkable specific heat, to which nothing but water approximates.

32. The specific heats of bodies must evidently vary with the states of aggregation in which they happen to exist. In the solid state, the tremor of the angles must be much impeded by the state of cohesion in which they are retained; yet, it may so happen that the particles may be retained in cohesion, by regions not of a vibratory character; and these, even in the solid state, are consequently free to become warm. Hence, though it may generally be expected, it does not necessarily follow, that a great change in capacity or specific heat shall always accompany a change from the solid to the

liquid state. That condition of matter, which is compatible with the greatest specific heat, is the aëriform; and the specific heat must be greater, the less the gaseous volume is made to approximate the dense state by compression. Hydrogen gas possesses so intense a heat, and capacity for more, that when a stream of it is made to play upon a body easily heated,—that is, such an one as is fixed and dry, and does not give off its heat rapidly to contiguous parts, as very fine platina, palladium, rhodium, iridium, or osmium foil or dust, or even charcoal, glass, pumice-stone, or porcelain, if they have been aided by an elevation of temperature,—so much heat is developed by the hydrogen, that the particles of the body, on which the hydrogen impinges, become red hot, the hydrogen unites with the vital air of the atmosphere, and water is formed.

33. Every change in specific heat is, of course, the consequence of the vicinity of other bodies, and of a change in capacity. When capacity increases by change of state, contiguous bodies supply heat to the matter whose capacity is increased; hence rarefaction must produce cold in contiguous bodies, such as air, thermometers, the hand, &c. In the fountain of Hero at Schemnitz in Hungary, the air is compressed by a column of water 260 feet high, or is about eight times as dense as that of the atmosphere; nevertheless, in consequence of principles that have been already explained, even in this compressed state, there is a quantity of steam or aqueous vapour in it, and when a stopcock is opened, so as to allow the rarefaction of the air, its capacity for heat is so much increased, that, borrowing from the aqueous vapour, it deprives it of the degree of heat alone capable of sustaining water in the aëriform state, the vapour congeals, showers down as snow, and icicles are formed around the pipe whence the air rushes *. If, then, there be two equal volumes of air, one of which is only half the density, or contains only half the number of particles which the

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* Davy's Elements, p. 91.

other contains, the volume of rare air will contain more than half the quantity of heat which the dense volume contains, and, in suffering compression to the same density as the other, a rise of temperature must be indicated. It must, in consequence of a diminution of capacity, part with some motion which it could sustain before, and thus it must warm contiguous bodies. In the same way, air of any density, when compressed, must give out part of its heat; but, in those experiments of sudden compression, which are commonly adduced to shew the great specific heat of gases, and their diminished capacity when compressed, much heat is generated by the violence of the stroke, and, probably, the volume, when restored to its natural density, would be found warmer than before the experiment. When two baloons, each containing a delicate thermometer, are united by a stop-cock, and one of them exhausted of air, while the other retains it of any density, on opening the stop-cock, and permitting the air to become equal in both, that thermometer which only was previously invested by the air, sinks, and that on which the air is let in, rises by the quantity that the other sinks. The temperature of the thermometer, confined along with the air, was sustained by the action upon its bulb of a certain number of particles of air, and, consequently, existed in a certain quantity of heat. When the air was permitted to escape, the number of warm particles clothing the bulb became less, and its temperature fell proportionally. But what it lost was gained by the other; so that its temperature rose in the same proportion. The calorific cause is transferred from one to the other, and the change of temperature indicated is proportional to the number of particles transferred, that is, to the change in the density. With different gases, the amount of the change of temperature depends on the specific heat of the gas. But the loss in density, when it is considerable, must be accompanied with an increase of capacity, which will sensibly affect the result: and hence the cold indicated by the thermometer, from which the air rushes out, ought, when the rarefaction is considerable, to be greater than the heat indicated by the thermometer, upon which the air is let in. These results are invariably found in the beautiful experiments of M. Gay Lussac, to which allusion is now made.* But in all experiments upon the heat of gases, the radiant medium, afterwards to be considered, modifies the results.

The compression of solids, when their parts yield, also diminishes their capacity; and as, in the condensed state, they cannot entertain the same quantity of heat at the same temperature, they must give it out, and warm surrounding bodies. It appears, from the experiments of Berthollet and others, that the quantity of heat thus developed, is proportional to the amount of condensation; and that bodies, whose parts are not moved, may be severely pressed without becoming sensibly warm†. It is well known, that, by continued percussion, a rod of iron may be made red hot; but, during the process, its texture undergoes a change, and to repeat the experiment, it must be forged into its former condition.

34. Such are the most obvious chemical and physical phenomena of heat, considered by itself. The consideration of fire, or heat and light simultaneously exhibited, will be afterwards entered on; meantime it may be only remarked, on the mechanical nature of heat, that, while it is said to be a tremor of the tremulous parts of the ultimate atoms of bodies, it is obviously only remotely connected with those movements which depend on the elasticity of the mass. This is a phenomenon arising chiefly from its subtile matter. When an ivory ball impinges on a plate of marble, the shapes of both are altered. The particles, though constituting a solid, are in reality suspended in a medium of subtile matter, and it is this chiefly that suffers compression, and of which the recoil produces the sensible rebound. The impression on one side is immediately intimated and induced on the opposite side, and the centre of elasticity remains

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* Memoires d' Arcueil, tom. i. p. 181. † *Ibid.* tom. ii. p. 441.

quiescent; and so far this, the elasticity of the mass, arising chiefly from its subtile matter, serves to illustrate atomic elasticity, which, when in action, is heat. But it might be expected, that masses which are not elastic would, upon the whole, be more easily heated by impact, than such as are elastic; for the yielding and change of shape, without rupture of parts, in the latter, indicates that the atoms can move freely in their subtile matter, and thus, to a certain extent, escape from the effects of percussion.

35. Besides the expansions and contractions of bodies, by which these changes of heat are indicated, we obtain intimation of the same by sensation. There is a certain amount of atomic motion in the matter of our bodies, which constitutes an agreeable warmth, and is most compatible with the circulation of our fluids, with those unions and decompositions in which assimilation consists, and the vital functions, generally. Any departure from this state is intimated at any part of the body, by a sensation of heat or cold. It has been usual to explain all sensation on the principles of vibrations; it need not be wondered then, if heat, according to this view, excite sensation. When the temperature felt departs beyond a certain quantity, from that which is natural to the system, the disorganization and death of the part chilled or burned, ensues. The organic tissue, when in life, cannot support the heat of boiling water, even for a moment, without a new distribution of the scalded parts being induced. Great cold is equally fatal, and is said to produce a sensation very similar. But a living body may be included in an atmosphere, whose action on a mercurial thermometer is much greater than boiling water, without sustaining any injury.

36. Speaking of heat, Sir H. Davy says, "It seems possible to account for all the phenomena of heat, if it be supposed, that, in solids, the particles are in a constant state of vibratory motion, the particles of the hottest bodies moving with the greatest velocity, and through the largest spaces; that in fluids and elastic fluids, besides the vibratory motion, which must be conceived greatest in the last, the particles have a motion around their axes with different velocities, the

particles of elastic fluids moving with the greatest velocities; and that in etherial substances, the particles move round their own axes, and separate from each other, penetrating in right lines through space. Temperature may be conceived to depend upon the velocities of the vibrations; increase of capacity, on the motion being performed in greater space; and the diminution of temperature during the convertion of solids into fluids or gases, may be explained on the idea of the loss of vibratory motion, in consequence of the revolution of particles around their axes, at the moment when the body becomes fluid or aëriform, or from the loss of rapidity of vibration, in consequence of the motion of the particles through larger space."[*]

Count Rumford says, "In reasoning on this subject, we must not forget to consider that most remarkable circumstance, that the source of heat, generated by friction, in these experiments, appeared evidently to be inexhaustible. It is hardly necessary to add, that any thing which any *insulated* body or system of bodies can continue to furnish without limitation, cannot possibly be a material substance; and it appears to me to be extremely difficult, if not quite impossible, to form any distinct idea of any thing capable of being excited and communicated in the manner in which heat was excited, and communicated in these experiments, except it be MOTION[†]. Dr Young, in his lectures, expresses the same opinion, and regrets that the philosophers of the present day are disposed to rest satisfied with superficial views of these matters. Sir Isaac Newton says, "Do not bodies and light act mutually upon one other, that is to say, bodies upon light, in emitting, reflecting, refracting, and inflecting it; and light upon bodies for heating them, and putting their parts into a vibrating motion, wherein heat consists?"[‡] The opinions of the admirable BOYLE are the same [§]; and these are only English philosophers.

It might, indeed, be shewn, that all the principles of modern chemistry, and the chief of those respecting the constitution of matter, advanced in the preceding pages, are found in the thoughts of the incomparable Newton. Even in the 31st query of the Optics alone, the following among other ideas are contained:—"Have not the small particles of bodies certain powers, virtues, or forces, by which they act at a distance, not only upon the rays of light for reflecting, refracting, and inflecting them, but also upon one another for producing a great part of the phenomena of nature? . . . Perhaps *electrical attraction*[*] may reach to such small distances as hitherto escape observation, even without being excited by friction. *For*, when salt of tartar runs per deliquium, is not this done by an *attraction* between the particles of the salt of tartar and the particles of the water which float in the air, in the form of vapours? And why does the common salt, or vitriol, (protosulphate) of iron not run per deliquium, but for want of such an attraction? Or why does not salt of tartar draw more water out of the air than *a certain proportion to its own quantity*, but for want of an attractive force, after it is satiated with water? And whence is it but from this attractive power, that water, which alone distils with a gentle luke-warm heat, will not distil from salt of tartar without a great heat?—and when water and oil of vitriol, poured successively out of the same vessel, grow very hot in the mixing, does not this *heat argue a great motion* in the parts of the liquors? And does not this motion argue that the parts of the two liquors, in mixing, coalesce with violence, and by consequence, rush towards each other with accelerated motion?—When spirit of vitriol, poured upon common salt, or saltpetre, makes an ebullition with the salt, and unites with it; and, in distillation, the spirit of the common salt, or saltpetre, comes over much easier than it would do before, and the acid part of the spirit of vitriol stays behind; does not this argue that the fixed alcali of the salt attracts the acid spirit of the vitriol more strongly than its own spirit, and, not being able to hold them both, lets go its own?.....*the air*

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[*] Elements, p. 95. [†] Essays, vol. ii. p. 492. [‡] Optics, p. 314.
[§] Boyle's Works, fol. vol. iii. p. 575.

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[*] The *italics* introduced in this quotation are not in the original.

abounds with acid vapours, fit to promote fermentations, as appears by the rusting of iron and copper in it, the kindling of fire by blowing, and the beating of the heart by means of respiration.....Now, the above mentioned motions are so great and violent, as to shew, that in fermentations the particles of bodies which almost rest, are put into new motion by a very potent principle, which acts upon them only when they approach one another, and causes them to meet, and clash with great violence, *and grow hot with the motion*, and dash one another into pieces, and vanish in air, and vapour, and smoke. When salt of tartar per deliquium, being poured into the solution of any metal, precipitates the metal, and makes it fall down to the bottom of the liquor, in the form of mud; does not this argue that the acid particles are attracted more strongly by the salt of tartar than by the metal, and, by the strongest attraction, go from the metal to the salt of tartar? When oil of vitriol is mixed with a little water, or is run per deliquium, and in distillation, the water ascends difficultly, and brings over with it some part of the oil of vitriol, in the form of spirit of vitriol; and this spirit being poured upon iron, copper, or salt of tartar, unites with the body, and lets go the water; does not this shew that the acid spirit is *attracted* by the water, and *more attracted* by the fixed body than by the water, and, therefore, lets go the water to *close* with the fixed body?"

When metals, corroded with a little acid, turn into rust, which is an earth, tasteless, and indissoluble in water; and this earth, imbibed with more acid, becomes a metallic salt, and when some stones, as spar of lead, dissolved in proper menstruums, become salts; do not these things shew that salts are dry earth and watery acid, united by attraction, and that the earth will not become a salt, without *so much* acid as makes it dissoluble in water? Do not the sharp and pungent tastes of acids arise from the strong attraction, whereby the acid particles rush upon the tongue? and when metals are dissolved in acid menstrua, and the acids, in conjunction with the metal, act after a different manner, so that the compound has a different taste, much milder than before, and sometimes a sweet one; is not this because *the acids adhere to the metallic particles*, and thereby loose much of their activity? and if the acid be in too small a proportion to make the compound dissoluble in water, will it not, by adhering strongly to the metal, become inactive, and lose its taste, and the compound be a tasteless earth? for such things as are not dissoluble by the moisture of the tongue, act not upon the taste.—*So a particle of a salt may be compared to a chaos; being dense, hard, dry, and earthy in the centre, and rare, soft, moist, and watery in the circumference.*

If a very small quantity of any salt or vitriol be dissolved in a great quantity of water, the particles of the salt or vitriol will not sink to the bottom, though they be heavier in space than the water, but will merely diffuse themselves in the water, so as to make it as saline at the top as at the bottom. And does not this imply that the parts of the salt or vitriol recede from one another, and endeavour to expand themselves, and get as far asunder as the quantity of water in which they float will allow? And does not this endeavour imply that they have a repulsive force, by which they fly from one another, or, at least, that they attract the water more strongly than they do one another. When any saline liquor is evaporated to a cuticle, and let cool, the salt concretes in regular figures, which argues that the particles of salt, before they concreted, floated in the liquor in rank and file, at equal distances, and by consequence, that they acted upon each other by some power, which, at equal distances, is equal, and at unequal distances is unequal.—And since the particles of Iceland crystal act all the same way upon the rays of light, for causing the unusual refraction, may it not be supposed, that, in the formation of this crystal, the particles not only arranged themselves in rank and file, for concreting into regular figures, but, *by some kind of polar virtue, turned their homogeneal sides the same way.*

The parts of all *homogeneal* hard bodies, which fully touch each other, stick together very strongly; and for explaining how this may be, some, &c. *I had rather infer, from their cohesion, that their particles attract one another by some force, which, in immediate contact is exceedingly strong, at small distances performs the chemical operations above mentioned, and reaches not far from the particles with any sensible effect*.....All bodies seem to be composed of hard particles.....Now, if compound bodies are so very hard as we find some of them to be, and yet are very porous, and consist of parts that are only laid together, *the simple particles which are void of pores, and were never yet divided*, must *be much harder*.....And how such very hard particles, which are only laid together, and touch only in a few points, can stick together, and that so firmly as they do, without the assistance of something which causes them to be attracted or pressed towards one another, is very difficult to conceive.....By the same principle (capillary attraction), a sponge sucks in water; and the glands in the bodies of animals, according to their several natures and dispositions, suck in various juices from the blood.

There are, therefore, agents in nature able to make the particles of bodies stick together by very strong attractions; and it is the business of experimental philosophy to find them out. Now, the smallest particles of matter may cohere by the strongest attractions, and compose bigger particles of weaker virtue; and many of these may cohere and compose bigger particles, whose virtue is still weaker; and so on, for diverse successions, until the progression end in the biggest particles, on which the operations in chemistry and the colours of natural bodies depend, and which, by cohering, compose bodies of a sensible magnitude. If the body is compact, and bends or yields inwards to pressure, without any sliding of parts, it is hard and elastic, returning to its figure with a force rising from the mutual attraction of parts; if the parts slide upon one another, the body is malleable and soft; if they slip easily, and are of a fit size to be agitated by heat, and the heat is big enough to keep them in agitation, the body is fluid.—Seeing, then, the variety of motion which we see in the world is always decreasing, there is a necessity of conserving and re-recruiting it by active principles, such as are the cause of gravity, and the cause of fermentation, by which the heart and blood of animals are kept in perpetual *motion and heat*, the inward parts of the earth are constantly warmed, and, in some places, grow very hot, bodies burn and shine, mountains take fire, the caverns of the earth are blown up, and the sun continues violently hot and lucid, and *warms all things by his light.* For we meet with very little motion in the world besides what is owing to these active principles; and if it were not for these principles, the bodies of the earth, planets, comets, sun, and all things in them, would grow cold and freeze, and become inactive masses; and all putrefaction, generation, vegetation, and life would cease, and the planets and comets would not remain in their orbs. All these things being considered, it seems probable to me, that God in the beginning formed matter in solid, massy, hard, impenetrable, moveable particles, of such sizes and figures, and with such other properties, and in such proportion to space, as most conduced to the end for which he formed them..........And, therefore, that nature may be lasting, the changes of corporeal things are to be placed only in the various separations and new associations and motions of these permanent particles, compound bodies being apt to break, not in the midst of solid particles, but where those particles are laid together, and only touch in a few points. It seems to me, farther, that these particles have not only a *vis inertiæ*, accompanied with such passive laws of motion as naturally result from that force, but also, that *they are moved by certain active principles*, such as that of gravity, and that which causes fermentation and the cohesion of bodies......Now, by the help of these principles, all material things seem to have been composed of the hard and solid particles above mentioned, variously associated in the first creation, by the counsel of an intelligent agent, for it became him who created them to set them in order And if he did so, it is unphilosophical to seek for any other origin of the world, or to pretend that it might arise out of a chaos by the mere laws of nature, though being once formed, it might continue by those laws for many ages. ……And if natural philosophy, in all its parts, by pursuing this method (analysis), shall at length be perfected, the bounds of moral philosophy will also be enlarged. For, so far as we can know from natural philosophy, what is the First Cause, what power he hath over us, and what benefits we receive from him, so far our duty towards him, as well as towards one another, will appear to us by the light of nature."

Such are some of the ideas of this great philosopher, respecting the constitution and origin of matter. Since his day, a multitude of minor discoveries has been made; above all, the admirable exploit of insulating the acid vapours, which he recognized as abounding in the atmosphere, and causing the rusting of metals, fermentation, and the circulation of the blood, has shed a new aspect over the science; but it is not to be denied that the progress of chemical theory, since his day, has merely consisted in an expansion of these views.

37. By means of these motive forces and conditions of motion, the constitution of bodies is sustained in a state of constant change, and there are more, particularly four, aspects assumed by matter, with the structure of which it is necessary to be acquainted. These are, the solid, the liquid, the gaseous, and the vapoury; solids, are such as can sustain their shapes by their proper cohesion, liquids are such as fall down in consequence of the generic or atomic attraction of the mass being greater than the specific or particular attraction, and they depend for their shapes on the vessels which contain them; and aëriform bodies, whether permanent gases or vapours, are in the same predicament. The distinction between gases and vapours arises from the permanency in the condition of the subtile matter of the one, and its changeable character in the other. Thus, if a particle have a great specific heat, compared with the whole range through which it may be heated or cooled, in nature or experiment, changes of temperature will most probably not alter its state, for the

amount of the change induced in the relative quantities of attractive and repulsive matter around it, is inconsiderable. If, again, a particle have such range of action that it may be made to alternate between a very hot state and a very cold state, a proportionally great change will be induced upon the relative quantities of its attractions and repulsions, and more easily may it be made to change from the aëriform to the liquid or solid state. This change, however, may obviously be effected otherwise than by a change of temperature. Thus, if by an electric discharge, the intensity or quantity of the electric or repulsive matter, investing each one in a volume of particles in the aëriform state, be lessened, a vapour may condense in consequence of its attractive influences being laid naked by the loss of a certain depth in its investing repulsive sphere. Compression may obviously effect the same; and it may be anticipated that this is an agent of great force. It is, in fact, equivalent to inducing a difference in electric state among the particles; the atomic parts are brought sufficiently contiguous to clasp each other by their attractions, which being consecutive, stretch out towards each other the more the particles are made contiguous; and do not suffer compression towards the solid matter which they invest, as is the case with the nonconsecutive repulsive medium which insulates them. Compression, then, effected without violence, so as to excite heat, which is calculated to sustain the aëriform state, must be a powerful agent in effecting the condensation of aëriform bodies. Some aëriform bodies, in which there is a very critical balance between the attractive and repulsive energy, may yield to a small pressure; and yet, while uncompressed, be most eminently elastic. But such is the harmony of things, that media of this structure must also have a great capacity for heat, and, consequently, a proportional tendency to sustain the aëriform state by the exhilarated state of their electricity, and the depressed state of their attractions; and the pressure which forces the particles towards each other may heat them, and consequently increase their elastic force.

Considered in a state of repose, and apart from bodies to compress them, or towards which they may fall, there is no generic distinction between matter in the solid, liquid, gaseous, or vapoury state. All are elastic not spontaneously expansible tissues of atomic particles, occupying a definite volume, and more or less completely insulated, and retained in position by the subtile matter which invests them. Solids and liquids cannot be compressed into smaller volumes to any great extent. At that degree of depth by which their atomic parts are separated from each other, their subtile matter is very dense, and requires an immense force to make it yield. Aëriform bodies, again, may be compressed into very small volumes, because the medium which insulates them is at so great a height above the atomic surfaces of the particles, rare and easily resisted.

At the surface of the earth, aëriform bodies are always in a state of compression, and hence, their true characters cannot be discovered by experiment. Immediately on removing the force which oppresses them, they expand, as nearly as they are permitted, to a state of natural tenuity; and, in this state, they can only be obtained at the surface of the earth, in a perfect Boylean vacuum. This circumstance, that aëriform media are always presented to us in a state of compression, naturally leads us to regard them as more peculiarly elastic and expansible than other bodies, and that they possess these properties different in kind, as well as in degree, from more dense bodies, that, whereas the particles of other bodies must first be made to approach each other before their elasticity is exhibited, aëriform bodies expand first. We are apt to forget that they are already compressed to our hand, and that their expansion is merely the recoil from a compression previously inflicted on them. An uncompressed aëriform medium, then, is a symmetrical tissue of atomic particles, which are more free to move, independently of each other, than particles in any other state. If several be removed, the volume is proportionally diminished, and the others come in, and, occupying their positions, restore the symmetry of the whole. A volume of an uncompressed gas is like a vessel full of small ivory balls, each similarly to another traversed by magnetic needles, suspended in a liquid medium, whose specific gravity is less than their own, by the least quantity. If one of them be thrown into a state of elastic vibration, which is propagated equally around from the centre, radii of elastic tremor will be propagated in the direction of all those which touch it around. Each of these receives the impulse which excites it on a point; its elastic movement is, therefore, determined between that point and one diametrically opposite. The next ball, or that second from the central source, is agitated in a like manner. Thus, in an uncompressed gas, an elastic impulse, propagated from a centre, is soon divided into radii, while the intervals remain more or less quiescent. In a compressed gas, on the other hand, the whole tissue resembles one ivory ball. The whole is in a state of mutual dependence and connexion. When one part is moved, there is a re-action through the whole. There is *undulation*, while, in the other case, there is *radiation*.

BOOK II.

OF

RADIANT MATTER.

THAT the intervals between the dense bodies of the universe are filled with particles of some sort, no one will dispute. This celestial medium philosophers have sometimes called Light, sometimes Lumeniferous Ether; and while all agree that it consists of particles possessing mechanical properties, some think that these particles move through two hundred thousand miles in a second of time; others, that their excursions of utmost amplitude are never more than twenty-five millionth parts of an inch. Moreover, these particles or molecules are admitted to have perfect uniformity of action in the same circumstances,—to submit to the ordinary laws of the impact of elastic bodies,—to have sides and properties peculiar to certain regions, and still they are treated of with some reservation as if they were different from matter and every thing else. This has arisen, in no small measure, from the reluctance of philosophers to admit any thing possessing inertia into the planetary spaces, lest such a medium might occasion a retardation in the heavenly bodies, which are commonly believed to move without any mechanism to sustain their motions.

But without a knowledge of the mechanism of such a medium, we cannot infer *a priori*, whether its inertia shall be of avail to bring a body in contact with it to rest, or to cause it move through it. Let us see what we find around us, and in the sky between the stars, and, in the mean time, leave planets, moons, and double stars to themselves, assured, that, though our philosophical notions respecting their movements may be a retardation to our progress in knowledge, they can be no retardation to them in their orbits.

According to the general principles which have been already advanced, it follows, that the lumeniferous ether, medium or substance of fire and light, radiant medium, or universal ether, to be any thing possessing physical properties at all, must only be regarded as atomic invested with its proper quantity of subtile matter; and, consequently, it must be a ponderable body, unless its specific heat be so great that its attractive energy is reduced to zero; for it is never to be forgotten, that the weight of a body is merely the effect of its attractive energy, causing it to tend towards the earth. Farther, it must obviously be either a gas or a vapour, and it must conduct itself like other gases and vapours, in as far as its atomic form is analogous.

We are, therefore, at once excluded from the consideration of all the doctrines of the system of emanation. All excessive penetrating power is likewise denied to the particles. Light must find its way through solid yards of quartz, otherwise than by the transmission of hard particles. There can be no doubt, however, that the particles of the radiant medium are more minute than those of all other bodies; but still it is incredible that quartz, glass, and such like bodies, can be so porous as to permit any particles to pass through them in right lines.

From an investigation of the phenomena of physical optics, afterwards to be illustrated, it is inferred in this work, that the radiant medium consists of particles symmetrically related and fixed in their positions by their mutual attractions; and that they are uniform in size, and that their shape is the regular tetrædron (Fig. 2.). These atoms are, like the particles of all other bodies, invested with their subtile matter; and their impenetrable nuclei are easily susceptible of that motion in which heat consists. The amount of the intervals between the atoms is different in different parts of the universe. It cannot be ascertained, but their symmetry may be determined from the laws of polarised matter, already discussed. The atoms must front each other, angle to angle; and as there are four such, the whole must be distributed, so that the spaces between the atoms are regular octædrons, all the edges of the atoms being in straight lines, inclined to each other at angles of 60° and 120°.

The smallest portion which possesses polarized unity, is composed of eight atoms, enclosing an octædral cavity, of which four are represented in Fig. 22., viewed almost as a solid, for the sake of simplicity of figuring. This form is an octædral trigonal icositetrædron, the external angles of the pyramids being coincident with those of a cube; or, if tangent planes be laid on four angles at once, a cube is developed, and the external edges of the constituent atoms are diagonals to the faces on every side.

Like the single tetrædron, as has been mentioned, (15) this octonate molecule is passive as to the direction of its polarity, and any of the three axes of the included octædron may become the polarized axis; but it is never to be forgotten, that whatever axis be the polarized axis, the equator, or plane containing the other two, retains the subtile matter in a state consecutive to that of both poles, as illustrated, (16). Now, it is to be remarked of the edges of the tetrædrons fronting each other at the equator, that they lie transversely to those on the polar aspects, while these latter are parallel to each other, (Fig. 22). It is also to be remarked, that all the edges, which lie in the same plane, cut each other at right angles.

Each octonate molecule of radiant matter is surrounded on all its six aspects, by others symmetrically fronting it; so that a perpendicular from the centre of any of its faces (that is, from the point of intersection of the edge produced), even if continued from a fixed star to the earth, would be the axis of a square prism, perfectly straight throughout, Fig. 22.; provided the density of the medium remained uniform or varied so that the condensation is expressed by any whole number or fraction whose numerator is unity.

Every octonate molecule is composed of four parts symmetrically related to each other, each of which consists of two tetraedons, of which five are represented in Fig. 24., having their most remote edges parallel to each other, their internal edges also being parallel, but in a transverse position to the external edges.

Each perfect ray of ether consists of four rectilineal fibres of tetraedrons of this character, which may be called single rays, (Fig. 24.) At equal distances, such a ray is axotomous in one plane; and at equal intermediate distances it is axotomous in another plane, at right angles to the first; and the positions of transverse frangibility are alternate to each other, and the intervals between them all are equal. If the even numbers 2, 4, 6, 8, 10, represent the positions from the base at which it is frangible in one direction, then the odd numbers 1, 3, 5, 7, 9, 11, &c. will represent the positions in which it is frangible in a transverse direction.

Every ray composed of octonate molecules, (Fig. 22.), or any number of such rays symmetrically arranged, are composed of single rays, (Fig. 24.), or rays composed of binate molecules, in two positions only, transverse to each other, in equal numbers; so that in any plane, half the ray is axotomous in one plane, and the other half axotomous in a plane at right angles. Such are some of the most important characters of the radiant medium, considered as a quiescent mass anyhow subjected to cleavage.

Viewed as a polarized medium, we must regard it in its molecular character as composed of tessular molecules, depending upon the direction in which the excitement of the subtile matter of the medium is propagated, for the direction of their polarity; but always possessing such a distribution of it, that the opposite aspects are in the same state, and the intermediate region or equator in a consecutive state. *Hence, one tetrædron constitutes a polarized axis; the opposite edges are in consecutive states; and it is to be remarked, that they are in a transverse position.*

It has been remarked, that the symmetry of the medium is sustained by the angular attractions of the atoms; and this, according to the principles already advanced (10.), is equivalent to asserting, that the ether is a gravitating medium. Hence, the ether must exert a pressure near the earth, and 100 inches of it must possess a certain weight. But how shall we discover either the one or the other? In treating of the habits of the common chemical bodies, it was shewn that every solid or liquid mass, in any degree of a volatile nature, gives off even its own particles to constitute an aëriform atmosphere around it,—particles which, compared with the ethereal atoms, are heavy, and cohere to their proper masses generally by many angles. Now, all bodies, as will be afterwards shewn, in reference to so great a number as to leave scarcely any doubt as to the rest, are ultimately composed of ethereal atoms, or may be resolved into them. If, then, they are able to disengage their own heavy particles until an atmosphere of due density be constituted around them, doubtless a less effort will be adequate to disengage a quantity of radiant matter from their substance, until an atmosphere of due density be constituted around them also. Thus, *radiant matter is the common vapour of matter*, it can be given off with greater or less ease from every substance; and the attempt to develope any region from which it is excluded, except by that region being filled by dense matter, will, perhaps, never be successfully made.

Judging from the character of the form of the ethereal atom, we should infer, that it rather belonged to the class of vapours than of permanent gases. When in a quiescent state, it must be more tense, rigid and fixed, than any other medium, except that of the vapour of iron, afterwards to be illustrated. Its particles will be mechanically displaced only with great difficulty. The lines of polarized attractions run through the whole volume, without any interruption, and are rectilineal. Every particle is bound in four equidistant points. Any other form can roll more easily. The inertia of the atoms is also a minimum; and the recovery of their position, if any should chance to be displaced, is most easy. Any aëriform medium may be retained symmetrically in the octædral cavities between the atoms, and be blown from one cavity to another, either in a rectilineal course by the pressure of the aërial particles behind them, acting in a single direction, or in a resultant course, from the action of two or more forces, such as converging winds or a stream of excitement shot along the ethereal rays in a certain direction, which being recognised by the particles of air (that are ultimately composed of ether) may act as a repulsive obstacle, and deflect the aërial current, bending its course, or causing it to circulate, as the case may be.

That which is most prejudicial to the fixedness and symmetry of the ethereal tissue, is a powerful calorific excitement, which diminishes the attraction, exhilarates the electric energy, and produces the disposition to rotate in the medium with which it is interlaced. Hence the imperfection of vision through hot laminæ of air, such as dance above hot sands and soils, flues, chaufers, and the like. But this very fixedness in the ether, indicates in it a critical subsistence as an aëriform medium, and without the most perfect repose,—without insulation from specific bodies, which might react upon it so as to dispose it into their forms,—or, in a strong state of electric transmission, the ether might be expected to be easily condensed into the substance of the bodies contiguous to it, or into those most immediately arising out of the union of its atoms. But though thus easily condensible, its elasticity in the aëriform state must be the most perfect of all bodies, for its symmetry is the most perfect, its inertia is the least, and the quantity of subtile matter in proportion to that of the atomic matter, is the greatest. In every feature, then, it seems calculated to elude the detection of the chemist.

The radiant atoms remain concealed wrapt up in pure light, and rendering all things visible by becoming invisible themselves. They cannot be pumped out of the Boylean vacuum, being generated from all the surrounding parts. Neither does the vacuum of Torricellius in any degree exclude them; but the phenomena of their development in it are very interesting.

If a long barometer tube be very perfectly filled with mercury, as by boiling the liquid metal in it, which causes all air, vapour, and such impurities to escape, and then inverted in a cistern of mercury, it is remarked, that even though the bore of the tube be very considerable, as, for instance, half an inch in diameter, the mercury remains filling the whole, though it be many inches longer than the column which the pressure of the air is adequate to balance. But if some smart strokes be given to the glass, so as to excite a vibratory motion in the top of the tube, the mercury separates from the tube there; and, after oscillating upwards and downwards for some time, electric light being developed in the region which the mercury lately occupied, it settles at 29, 30 or 31 inches above the level of the fluid metal in the cistern, as the case may be. If, now, a drop of water be any how introduced into the Torricellian vacuum, similar phenomena are again produced; the mercury falls, and, after oscillating upwards and downwards, settles at a lower level. If alcohol be subsequently introduced, the same phenomena are repeated again, and the column is still farther depressed; and if a free entrance to the air, or that medium which presses it up, be admitted at top, so that the air on both extremities of the column shall be of equal density, the mercury sinks to the same level within as without. All these phenomena have the aspect of being perfectly analogous, and the depression seems in every instance to be occasioned by the presence of elastic matter enclosed in the hollow of the tube above the mercury, which balances a part of the pressure on the cistern without. This pressure is at all times the atmosphere and the radiant medium; but when, by the concussion upon the glass, opportunity is given for radiant matter to be disengaged from the mercury and the glass, this elastic medium is generated within, till its elastic force be as great as that without, and the mercury remains sustained by the air alone. No other phenomena than these could be expected, if the radiant medium exerted a pressure on the cistern, and it does not seem possible to explain them otherwise. The phenomenon has been said to arise from an attraction between the glass and the mercury. The mercury in a barometer is, in consequence of the mutual action of the mercury and glass, kept below the true level due to the pressure of the air, which indicates an attraction between them; and the same is proved by other experiments. But even though this were granted—even though there were such an attraction between the laminæ of mercury contiguous to the glass and the glass, as could sustain several inches of the external metal, still, how is the central part of the column to be sustained by such a cause? Has the mercury ceased to be fluid? It is well known that a cylinder of tin, or lead, or ice, may be congealed on the outside, and the liquid matter poured out from the centre; Why, then, is the central part of the mercurial column, which is at once singularly heavy and fluid in its consistence, not poured out, though it be completely inverted? On any other supposition than that of an external pressure which balances it, the phenomenon seems to be quite inexplicable; but it is just that which we should expect from the pressure of the radiant medium.

Except by the Torricellian experiment, which seems satisfactory enough, it is difficult to see how in any thing that has yet been done, the pressure of the radiant medium could have been detected. It is well known that it might exist to any extent on our bodies, without producing any sensation. The pressure of the atmosphere, indeed, which is of a palpable and gross kind, has only lately been discovered; and this medium we have the power of excluding completely from one side of a surface, so as to measure its pressure on the other, but the radiant medium remains of the same tension on both. Probably experiments may soon be discovered, which will irdicate its pressure pretty accurately; meantime, its pressure, whatever it may be, must not be confounded with the weight of a given volume, which is nowise dependent on it. A volume of hydrogen gas exerts the same pressure as an equal volume of vital air, though it weigh less than $\frac{1}{13}$th of the latter.

In the Torricellian vacuum, the radiant medium indicates its delicate constitution; for, on forcing up the mercury again, it either penetrates the mercury which ascends through it, is condensed into the state in which it was before it ascended, or suffers an extreme compression. Some aëriform matter is left, however, for the mercury cannot again be sustained at a higher level than that determined by the atmospherical pressure. That a considerable volume might be compressed into an invisible space (supposing that it could sustain such compression without condensation), may be inferred from the fact, afterwards to be illustrated, that one volume of air, if resolved into radiant matter, whose atoms were equally dense with the particles of the atmosphere, would expand into 20.4 volumes. Supposing 100 inches of air, then, to weigh 31 grains, an equal volume of radiant matter of the same (or the common) density, would weigh 1.502 grains. We are not to suppose, however, that this gives any idea of the weight of 100 inches of its natural density at the surface of the earth, or that in a Torricellian vacuum.

Now, it is evident, that, since the radiant is a gravitating medium, its density must vary with its proximity to the heavy mass which solicits it; and, therefore, it must exist around stars in a state of intensity proportional to their masses, supposing its temperature uniform. If, again, the calorific excitement derived from proximity to such stars were also proportional to their masses, the attractive energy of the radiant atoms, which enables them to be recognized by the heavy bodies, and to be condensed towards them, would be diminished, and the medium might perhaps remain of uniform density throughout; the richness of its properties, both as to gravitation and heat, preventing an interference with the uniformity of its symmetry, as completely as if it were destitute of both. It will be shewn, that a lumeniferous ray of radiant heat has such a form as that here implied, and is coldest at some point between its extremities; but we cannot discover the effect, even though it were proved that the calorific excitement of stars varied with their masses. Such as are suffering condensation, must, indeed, be in a state of intense heat at the surface; but it is much more probable that the radiant medium exists around stars in a state of density proportional to their masses, or the number of condensed radiant atoms of which they consist, with such departures from an exact proportion as differences in heat may occasion.

But its density will not increase down to their very surfaces. Their atmospheres being composed of radiant matter, and being more dense media, will admit only a certain quantity to be interlaced with them; and this quantity will be smaller the more dense the air is. Hence the distribution of air and radiant matter around the world, or any star, is in an inverse manner; the air is densest at the level of the sea, or solid surface, and rarifies in a geometrical progression as we ascend, till we arrive at the top of the atmosphere, where it is of a symmetrical and uncompressed structure; the radiant medium, again, is most dense towards the top of the atmosphere, becomes thinner as we descend, and, in the absence of positive evidence, and in consideration of the harmony of nature, it is very reasonable to conclude, that, as the air is at the top of the atmosphere in a state of natural or uncompressed density, so the radiant medium, at the surface of a star such as the earth, is in the same condition.

Here, then, we have that interlacement of substances on the great scale, which we every where observe on the small scale. The earth, however, is but a small star, and the compression of the radiant medium above its atmosphere must be comparatively inconsiderable. But, according to the view now suggested, the large planets, the sun and the fixed stars, must have shells of compressed radiant matter around them. It also follows, from the principles which have been laid down in reference to the reaction of subtile matter (19), that different aëriform media, in proportion as their forms make a nearer approach to radiant matter, must exert a greater repulsion towards it, or exclusive power upon it. The density and weight of the radiant atmosphere, radiant matter included, along with the volume of one gas, may, therefore, be very different from that included along with the volume of another, and both may be different from that without. Hence it obviously follows, that the balance cannot give us the weight of the matter of a gas included in an aëriform volume of the same; but always a resultant weight, which oscillates on both sides of the truth, according as the density of the included radiant matter is greater or less than that of the external. It will afterwards appear, that the atomic refractive power of the gases is a good enough index of the repulsive or exclusive action upon the radiant medium; and that the weights found by the balance must be altered a little, according as the atomic refractive power differs from that of common air. Here, again, we may remark, in passing, that as it is with specific heat, so it is with refractive power: hydrogen and oxygen are at opposite extremities of the tables, which is certainly very unfortunate, considering how much of the atomic philosophy has been reared upon their specific gravities.

The radiant matter, like all other substances, is capable of entertaining three sorts of motions:—

1. That arising from the polarity of its atoms.

2. That arising from the vibratory motions of its atomic angles.

3. That arising from compression and subsequent dilatation depending on the mechanical elasticity of the mass.

The first of these produces the glorious phenomena of light and colours, and the movement of gross bodies immersed in the medium; the second the genial warmth of radiant heat, and it is well known that the third, if it produce any discoverable effect at all, must only give rise to sounds.

OF LIGHT.

Light, in the common acceptation of the term, means that by which objects are made visible, and darkness that by which vision is prevented. That the terms Light and Darkness, in their vulgar sense (which is always to be much respected), do not express absolute states of difference, such as that between motion and rest, but merely modifications of the same state affecting our eyes differently, fully appears from this, that every species of animal, according to the organization of its eye, has a light and darkness of its own. To the human eye, in its best state, there is light over the face of nature all the hours while the sun is above the horizon, or not more than 18° below it. From this, perhaps, the body of the sun himself must be excepted, the disk of which, when attentively viewed in its greatest splendour, becomes dark, and the eye is reduced to such a state, that, for some time after, there is darkness over every thing as if it were midnight.

Animals have been divided, by naturalists, into two great groups, according to the relation of their eyes to light. Those to which the radiant movements of the day-time are most suitable, have been named diurnal animals; and those which see best during the night have been called crepuscular, or nocturnal. To the latter, the excitement incident in their eyes from bodies illuminated by the sunbeam, seems to produce an inconvenience somewhat similar to that which the direct gaze at the sun does to man. The eye, however, like the other senses of the inferior animals, has a range of functions far greater than in us; and some animals seem to be able to distinguish objects almost equally well by day and night. There are others again, more especially among annulose animals, to which it seems to become very speedily dark, and their vision seems to be confined to a few hours around mid-day. In physics, then, there is no absolute distinction between that state of the radiant medium which is said to be light, and that which is said to be darkness. The terms light and darkness, involve the consideration of the sensibility of the eye as well as the movements of the radiant atoms.

The philosophical meaning of the term Light is somewhat different; and different individuals use it in different senses. Most frequently it signifies the radiant medium as a whole, in that state, whatever it may be, which produces vision. Huygens treats with great precision of a lumeniferous ether composed of particles.* Newton generally speaks of rays of light, which he describes as, in some sense, hard bodies, which, at equal intervals, are in fits of easy reflection and easy transmission, whose two opposite sides are originally endued with a property on which unusual refraction depends, and other two opposite sides not endued with that property. He also says, "therefore every ray may be considered as having four sides or quarters, two of which, opposite to one another, incline the ray to be refracted after the unusual manner, as often as either of them are turned towards the coast of unusual refraction."† While he neglects the doctrine of emanation, his description of the structure of light is exactly that of a medium composed of particles, (as will be shewn) similar to that here advanced.

Light, according to the sense in which it is used in this work, signifies the subtile matter emanating from the facets, and all but the angles of the radiant atoms, and investing each as a repulsive sphere. In a state of unexcited repose, this fluid produces absolute darkness; in a state of polarized activity, it produces vision. To bring light out of darkness, then, it is only necessary to excite the subtile matter investing the radiant atoms; and to produce vision, it is only necessary to provide an eye that may be excited too, and a sentient principle on which the excitement of the eye may react. An atom of light can mean nothing else than a radiant atom; but the light of a radiant atom is the subtile, repulsive, or electric fluid that invests it, as the gravity of an atom is the subtile attractive fluid covering its angles.

A lumeniferous atom is a radiant atom, in a state of induced polarity. A ray of light is a series of atoms, along which the induction takes place; and a pencil of light is a fasciculus of such rays. A single ray of light (Fig. 24) consists of a single series of lumeniferous atoms; and a pencil, composed of single rays in a parallel position, (that is, with their edges, which are in the same plane, parallel,) may be called a singled pencil, or, when it is of great breadth, simply singled light. A perfect ray of light (Fig. 22) consists of four single rays in a transverse position two and two, as has been already explained. A pencil of such is a pencil of perfect light.

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* Opera Reliqua. vol. i. p. 9.

† Opticks, Qu. 26.

An octonate molecule of atoms, in a state of lumeniferous excitement, is a perfect molecule of light; and a perfect ray is composed of such. A single ray is, in like manner, composed of molecules, each constituted of two atoms. The half of any of these, or the distance between the polar aspect and the equator, which implies the quantity possessing consecutive polarities, one molecule being considered by itself, is a polarized axis, which may be called a chromatic axis of the least dimensions, and involves only one atom between pole and pole. Two successive molecules in a ray are always in opposite movements, and polarized states, at the same time; and the space by which they separate the two molecules included, may be called an interval. Such a lamina, then, in the excited radiant medium, is analogous to a thin disk with consecutive electricities on its opposite sides, and it includes in its breadth two molecules and four chromatic axes.

As all gross or sensible bodies are composed of radiant atoms, it follows that all material bodies contain light in themselves; which must, of course, be subject to excitement by the dissimilarity of the state of the contiguous radiant medium, or otherwise. Consequently, all bodies are capable of being illuminated; and, in some state of aggregation or other, it may be expected that all bodies may become visible, provided their mass be considerable.

Since atoms and molecules of light are passive as to either polarity, and will be negative or positive, according as the contiguous molecules which excite them are positive or negative, it follows that the radiant medium is the most perfect conductor of light or lumeniferous excitement between bodies in dissimilar states, that can be conceived; and that, in propagating light between dissimilar bodies only can its lumeniferous excitement be sustained to any very great distance. For a series of shells of radiant atoms surrounding any luminous body, if there be no dark body in the medium to receive their excitement, and render them fit for a new change, will repel each other, and each molecule will become insulated from another, so that the propagation of the excitement from the luminous body will be arrested, and the surrounding medium thrown into a state of tension and rest. A luminous body is one which, in consequence of some peculiarity in its structure, sustains its light in an excited state. A dark body is one whose light is in a state of neutralization and repose, or its polarity too weak to give rise to rays of light towards such as are darker. It is illuminated, when, by induction of the contiguous medium, the light of the superficial stratum is disposed into a state of free polarity; and it is visible, when the lumeniferous excitement has been propagated from it to the eye.

OF THE PHENOMENA OF EXTERNAL VISION.

It is abundantly proved by observation, that, when a luminous body is brought into the presence of such as are dark, they speedily become illuminated and visible. If the space between the luminous and dark bodies be not more than 200,000 miles, the illumination takes place in less than one second, or the time occupied in one oscillative movement of a pendulum about 39.139 English inches long; and for as many spaces as there are of this extent between the luminous and the dark body, the times of so many movements of the pendulum must be allowed before the lumeniferous excitement extend from the one to the other. Thus, if the Sun be distant 95,000,000 miles from the Earth, the excitement to which he now gives birth in the radiant atoms most contiguous to his photosphere, requires about eight minutes to be propagated through so great a distance, and in the case of the fixed stars, months and years must be required; although, like all other motions depending on polarized subtile matter, it pursues the shortest possible course between the bodies in dissimilar states.

If a ray of matter, perfectly hard and unelastic, extended from the sun to the earth, a movement towards the earth of the extremity at the sun would be simultaneously made at the earth; because a body perfectly hard cannot yield in its substance, and if one end moved while the other remained at rest, it must needs be yielding. But there is no such thing in nature as a body perfectly hard and unyielding. The most rapid transmission of motion with which we are acquainted, is in those media whose structure is most symmetrical, and the inertia of their particles the least. There are evidently two kinds of transmission, however,—a polarized and a mechanical, and the former surpasses the latter very far in velocity. The velocity of light is approximated by nothing besides, that can be observed; and it may be useful to have a clear idea of the mode of its propagation. Suppose, first, that there is a small luminous body, around which the radiant medium exists in a state of quiescence,—that is, neither compressed, nor in a state of polarized excitement. The instant that the body becomes luminous, the shell of radiant atoms most contiguous is attracted, in virtue of dissimilarity of state. If the surface of the body is in such a condition as to invite to cohesion, the radiant atoms may be added to its substance, become luminous, attract the next shell, and thus the mass of the body may increase. But this would reach a crisis, for there would soon be a coating of atoms which would repel others (being of their own kind) after having illuminated them, and the increment of the mass would be arrested. One shell, then, being illuminated and repelled, must act the part of a luminous body, and illuminate the next shell, which will first contract to meet it, then expand to recede from it. The innermost shell having received a fresh charge from the luminous nucleus, will charge again the second, which had become dissimilar, having imparted its charge to the third. But, in this state of things, the whole mechanism is quite analogous to a Leyden jar. Polarity is induced to a certain extent; but, unless the medium be relieved of its charge, the transmission ceases; all things remain in a state of tension, and the radiant shells are insulated from each other. The illumination is propagated to a greater or less distance, according to the intensity of the central body's luminousness; but it is like a heart that is throbbing. To sustain a regular systole and diastole, and transmit the subtile excitement to very remote parts, it is necessary that there be some dark body to form the base of the ray, which, by its constant tendency to a state of quiescence and darkness, has a constant faculty of neutralizing the contiguous radiant atoms, and thus of sustaining the lumeniferous rays that impinge on it.

But are lumeniferous rays shot out at random from luminous bodies, if haply they may chance to alight upon a dark body, and benefit it by their illumination? When a molecule at one extremity of a ray of light, lying contiguous to a luminous body, and between it and a dark body, moves towards the luminous body lit up that instant, it is removed from the next molecule. Now, the dark body, being in a similar state to that extremity of the radiant prism contiguous to it, must exert a repulsion upon it; but that extremity may move away; for there is no resistance in that direction, in consequence of the movement of the molecule of the end next the luminous body towards the luminous body,—the dark extremity will therefore be repelled in the direction of the luminous body; hence, it appears, that both the luminous and dark body conspire to cause a ray to strike between them. But without urging this illustration, which of course involves the idea of mechanical resistance in the medium in a state of excitement, it may be remarked that the case is perfectly analogous to that of a body rendered luminous by electricity. Let a point be electrified positively, a pencil of electricity streams up symmetrically through the radiant, each ray of electricity giving rise to lateral or secondary rays, which can only be of light, and which therefore render the electric pencil visible. While no body in a dissimilar state is near, the radiation is equal on all sides; but when a ball of metal held in the hand, or the hand itself, or any body dissimilarly electrical, is brought near, the electric rays strike between them to a greater distance, the symmetry of the radiation is destroyed, and an excess takes the direction of the dissimilarly electrified body.

From this view, it follows, that luminous bodies shall be more or less bright, according to the nature and number of the bodies which surround them; and does not a candle burn more brightly in a white room than in a black one, which constantly relieves it of all its excitement as fast as it takes place, while the white one sustains its lumeniferous excitement in a state of greater tension? Is not a white body in the focus of a concave mirror rendered less bright by the introduction of a black one into the conjugate focus, which relieves its excitement, and diminishes the tension to which it owes the intensity of those rays that enter the eye, and indicate its state as to light? In a word, would not the sun become far more subject to dark spots in his equatorial regions than he is now, if the number of planets in the region of space, corresponding to his equatorial regions and demanding his light, were greater than it is now?

The quantity of illumination, then, propagated between a luminous and an illuminated body, depends upon the quantity by which they are positive and negative, in reference to the condition of their light. The illuminating power of that which may be called positive, in reference to the darker, varies at different distances inversely as the square of the distance (supposing the temperature of the ray not to vary); because the number of the illuminated rays incident upon the same area varies in this proportion. But, between the same luminous body and dissimilar bodies illuminated by it, the lumeniferous action propagated in the different directions does not fall away as the square of the distance increases. One of the bodies, though at a greater distance, may be more strongly illuminated than another, in consequence of its condition giving rise to a more powerful re-action between them. Now, this re-action must be most powerful when their substance is most nearly the same, and their states as to lumeniferous excitement most different. Large planets, then, will be more powerfully illuminated by the sun than small ones, other things being the same; because the radiant medium around them is in a condensed state, and this being a similar substance to the medium through which the polarity is transmitted, the mutual re-action of the two subtile matters proper to each must be proportionally greater. Though the Sun, then, be nearly twenty times as distant from the planet Herschell as from the Earth, we are not to conclude, that the illuminating power of the sun at this star is only $\frac{1}{400}$th part of what it is at the earth. Were this the case, it is inconceivable that he could be visible to us. A stream of solar light will be shot out towards him and his satellites, of far greater intensity than that which the earth receives. Though the angular magnitude of the sun, as seen in the sky, be no larger than the planet Venus to us, it may irradiate his canopy with a brightness no less than ours. That he is not intrinsically luminous, follows from the phenomena of his satellites; and to demand that we should believe, that the illuminating power of the sun at his body is four hundred times less than at the earth, notwithstanding which he is visible, and of a clear white colour, is to ask something that is very incredible.

Such are the most remarkable phenomena of the radiation of light between the two extremities of a straight ray. But if the density of the radiant be increased by the gravitation of the star which it surrounds, so that it is in a compressed state, that must be a region of undulation as well as radiation. No doubt radiation is that action which polarized atoms, such as those of the medium of light, must be disposed to produce; for such polarized excitement must naturally be propagated in a straight line, from one edge to the next parallel edge, and so on, in the most exquisitely rectilineal manner, and as if there were nothing present besides, but the line of polarized atoms.

But where the radiant is in a compressed and dense state, besides primary rays, the institution of lateral rays, and oblique polarities, is highly probable. There must be a movement of the whole shell, of which, one part is moved by polarity; for the whole medium is, as it were, one solid body, all its parts being disposed to stretch and occupy the positions of the others. The rays of light then leaving the Sun's surface, where, by analogy, we may suppose the radiant to be as dense as it is in space, or at the earth's surface, are interrupted at the top of his atmosphere by a shell of compressed atoms, a region whose movements must be those of undulation, not of radiation. By-and-by, they escape through this region, and radiation is instituted again, and continued to the planets. Now, what would such a shell of undulating light be, but that glorious photosphere that surrounds him? And to what phenomena would such a mechanism give rise, but those very appearances, in all their details, which Sir William Herschell observed? According to this view, his photosphere consists of matter in the fittest of all possible states for a permanent and unfading luminousness.

But of all the bodies of our system, is the sun only provided with a photosphere? And what is the requisite mass which a star must possess, before it becomes thus invested? That the planet Mercury has none, is evident from the mountains of his disk being seen. The Moon, which is still less than he, is evidently equally naked. Next to these planets in smallness, is Mars, and though the phenomena presented by the illumination of his disk be very interesting, yet there is no evidence that he possesses a shell of undulating atoms around him. On the other hand, the redness of his colour indicates that we see his atmosphere, the great extension of which, no less than the smallness of his gravitation, would be adverse to the compression of the radiant medium around him. We cannot examine the aspect of the Earth, viewed as a star; but we can view Venus, which being nearly of the same size, must be nearly in the same condition, as to the compression of the radiant around her; but, from her greater proximity to the sun, her lumeniferous excitement must be more powerful. Now, astronomers generally assume, that she possesses a faintly illuminated region above her surface, and a crepusculum stretching into the dark region. Thus, her condition, in reference to the quantity of radiant matter above her atmosphere, like the quantity beneath her atmosphere, seems to be much the same as that of the earth. But neither the one nor the other affords unequivocal evidence that there is a region of atomic undulation above them, though they seem to indicate traces of such a state of things. The other planets, Jupiter, Saturn, and Herschell, are so much larger than the Earth, or Venus, that these views would induce us to believe that they all were invested with a canopy of undulating atoms, which, on the side turned to the sun, would be a photosphere, rendering the whole of their sky radiant on that side; and thus illuminating the diurnal hemisphere, while the nocturnal, as is well known, besides a considerable extension of the photosphere, giving rise to a great crepusculum, is illuminated by a number of satellites.

Such a state of things, respecting the intensity of solar illumination of the different planets, seems to follow, of necessity, from their known gravitation, and it relieves astronomy of a very unnatural deduction, as to the density of the matter of these stars. It is rather incredible, that the central parts of Jupiter and Saturn should be compressed by a column of planetary matter, thousands of miles long, and yet not be condensed, as we find that terrestrial matter is by a comparatively very small weight. Indeed, we cannot form any reasonable conjecture as to the state of the matter of these planets, if it be, as astronomers have calculated, such that it would not readily sink in water. If, again, we suppose that it is the photospheres of these planets whose angular magnitude has been measured while the nucleus remains unseen by us and of unknown extent, we may suppose that there are crystalline bodies there, composed of the same earths as in this world, and that the general state of things is analogous. As to their temperature, some remarks may be made afterwards.

We know that the sun has a photosphere, and his density overhead is scarcely more than that of water, assuming that, according to the experiments of Maskeline and Carlini, that of the Earth is about the same as heavy-spar, but the density of his nucleus must be greater. It was long supposed that there was a certain degradation in the density of the planets, as we recede from the sun; and, indeed, the matter of the remote planets may be in a highly expanded state; but it appears that there is no law that would induce us to infer that the density calculated from their gravitation, and the magnitude of their disks, is their true density. Certain it is, that this unaccountable lightness of substance is confined to those on which mountains have never been seen, and whose disks seem to be covered with fluid matter, in different states of illumination, at different times.

But another explanation of their specific lightness might be given, on the supposition that the matter occupying their central regions was in a state of absolute solidity, and not penetrated by polarity. In this case, it could have no weight. The only way in which the central parts of a planet can contribute to its weight, is by their being in the state of atoms, or matter endowed with attraction. Whatever view of this matter be adopted, however, the argument for their photospheres remains equally good. Being interlaced with their atmospheres, this undulating shell will revolve along with them.

According to this view, during our ignorance of the specific nature of the natural substances of which their superficial parts consist, we shall obtain an expression for the sun's illuminating power at these planets, identical with that which expresses the action of his gravitation upon them. For the amount of their photospheres is proportional to their masses, and the illuminating force of the sun at them decreases, like his gravitation, inversely as the square of the distance; and, therefore, the amount of solar illumination diffused over the face of creation upon them, like that of the stability by which all things are retained in position there, is expressed thus,

$$\textit{Illumination} = \frac{\textit{the mass}}{\textit{square of the distance.}}$$

But to return to the radiant medium around us, it may be remarked, that this is evidently a region of radiation, not of undulation. Lumeniferous excitement is not propagated into shadows, except as secondary rays to the pencils which pass the edge of intercepting bodies, but perseveres in straight lines, while the medium remains uniform, and while no interference takes place with other rays in an opposite movement.

It follows, that in many cases of the transmission of light, such an interference must occur, and a change upon the character of the light or darkness must be produced. Suppose two rays of light, whose molecules are moving through equal spaces, to be inclined to each other, so that they ultimately coincide or intersect each other. The radiant atoms which lie in the point of intersection, and are common to both, can only propagate the lumeniferous excitement transmitted along either, when they are not solicited to opposite polarities, or in opposite directions, and with equal force by the two rays, at the same instant. If the lengths of the two rays be equal, both will conspire to illuminate the common part with double intensity. The number of molecules in both rays being the same, the time occupied in the movement of both the same, and the movement of the first, or those most contiguous to the radiant point being at the same instant, the two molecules in the two rays contiguous to that which is common, are incident towards it at the same instant, and with the same polarity, and, consequently, excite it to a higher degree of illumination than if one only had been incident. If one of the rays contain one molecule more than the other, then the next which is common is solicited to opposite polarities, and, consequently, to opposite motions at the same instant, and the rays neutralize each other, and darkness ensues. If, again, one ray contain two molecules more than the other, the success is the same as at first, when the number was equal, for the common molecule is affected by the same polarity in both, and solicited to the same movement. Thus, two rays, consisting either both of an even, or both of an odd number of molecules, do not interfere with each other; but two rays consisting one of an even, and the other of an odd number, do interfere. Let A and B (Fig. 25.) be two rays, having a common origin, equidistant from both these points, and C a radiant molecule common to both. While the number of molecules of both rays is even, by commencing with the same polarity as +, it will always be found that the common part, exposed to induction from both rays, is approached by two molecules in the same state, and therefore has its polarity exalted. Let D and E again be two rays, which meet in the common molecule F, one of them consisting of an odd, and the other of an even number of molecules, it is evident, in like manner, that the common molecule is exposed to consecutive polarities at the same instant, and remains quiescent. If, then, two rays, having a common origin, and converging at a small angle, coincide at a surface capable of being illuminated, such as a card; and if we conceive the directions of these rays, while they always continue coincident at the surface of the card, to be altered, so that they move along from the point where both the rays emanating from the radiant point are equal,—in their progress, they will trace on the card a series of bright and dark fringes, bright when both rays contain either an even or an odd number of molecules, or when the common difference is two; and dark as often as one contains an even and the other an odd number of molecules, or when the common difference is one, or half that in the former case.

That is, when the difference in the length of two rays is an interval, (p. 81.), they conspire to produce brighter illumination at the radiant molecule which is common; when the difference is half an interval, they counteract each other, and produce darkness.

Such is the law of interference, deduced from the view of radiant movements here advanced; and it obviously corresponds with the law of Dr Young, in which the interference is supposed to be a mechanical effect, produced by the meeting of waves in opposite movements, the individuality and insulation of which, at other times, it is, however, impossible to conceive.

A consideration of much importance now occurs. Are the pulsations of the radiant molecules, or their oscillations on both sides of the position of repose, always of the same amplitude, and executed in the same time, or are they different in different circumstances? To preserve them uniform, it would be necessary that they always transmitted the same amount of polarized excitement; for in proportion as the polarity becomes stronger, the tension of the ray and the force of induction must both increase, and the latter may occasion movements through larger spaces; though these spaces, if the nature of the moving force remain the same, may be passed through in the same time. We will not hesitate, then, for a moment to conclude, that different rays are in different states of movement and tension, those molecules which move through the largest spaces constituting the most tense rays. But the propagation of light from one body to another, is a phenomenon exactly analogous to that of chemical union. There is nothing violent or mechanical in it; we may, therefore, trust that the light excited at the same body, in the same circumstances, will be always of the same nature, or give rise to an isochronous radiant excitement. Further, the condition or quality of the light proper to different chemical substances, cannot be always the same; but like their subtile matter, as exhibited in aggregation and electricity, it must receive a certain specific modification. Therefore, substances every way similarly constituted, will propagate constitutionally the same sort of light, while that will be different from dissimilar substances,—some will give light more highly positive,—some more highly negative, —some a greater quantity, others a less quantity,—and the differences between bodies in these respects will be as permanent as the other features in their chemical constitution generally, supposing that the medium which is to conduct their light to the eye is always in the same condition. Now, what effect upon our eye will this variety produce? We can observe two changes in the light emanating from bodies; one indicating brightness or intensity of illumination, the other indicating colours. All the phenomena connected with brightness intimate that its degree chiefly depends upon the number of excited rays propagated from the object considered, and not upon a difference in quality in the light. By diminishing the aperture of the eye, as by looking through a very small hole, the brightness of bodies is very much diminished along with the number of rays from them which enter the eye, their colours remaining unchanged. Brightness and dimness, then, without change of colour, seem to depend almost entirely upon the number of lumeniferous rays entering the eye from the visible object; and all coloured bodies may be bright or dim, according as the number of rays propagated from them is greater or less.

It remains, then, to ascribe the colours of bodies to rays transmitting different qualities of light, or light in different states of polarity, which give rise to intervals of different bignesses; and nothing could be desired to respond more satisfactorily to such a view, than all the phenomena of chromatics. It also agrees with the vulgar conceptions of things which lead us to regard the colour of a body as something peculiar to that body's substance, of which the light between the eye and that body is the index. The radiant molecules transmitting the modified light cannot accurately be called colours, because they are invisible, and an invisible colour is a contradiction in terms. The light proper to a surface, then, we may regard as the colour of that surface; the illuminated form developed in the back part of the eye, in consequence of its lenticular structure, is the inverted image of the visible object. But this image we must be careful not to confound with that excited spot of unknown form in the radiant tissue of the ulterior optic apparatus which in this work is generally called an image also.

As to the composition of lumeniferous rays existing simultaneously in the radiant medium, it may be remarked, that if we suppose that there is a multitude of rays of all sorts of light propagated in a direction nearly or altogether parallel, the laws of polarized matter lead us to expect that they will react upon each other, being analogous to chemical bodies in dissimilar electrical states. They will, therefore, group together into fasciculi which shall have the greatest degree of symmetry, and have opposite polarities in the centre and circumference of the transverse section of the ray, the region between them being, in reference to both, neither in a positive nor negative state. The medium being resolved into such prisms, becomes symmetrical in its structure; and being composed of similar bodies in the same electrical state, the rays will attract and change each other no longer, but rather repel each other, and thus each compound or fasciculated ray become insulated. If now, such a ray were very small and wholly solid, it would probably possess great unity of polarity, and any lamina taken from the prism would simply be a circulated axis, in one state of polarity on the external aspect, in another in the central region, and neutral between these all round: but a ray is not solid; in its structure it resembles two magnetic bars, each composed of parallel laminæ, interlaced with each other at right angles. The extremities of these laminæ are represented on the base of the ray, by the edges of the lumeniferous molecules, which consist of two sets parallel to two diameters at right angles to each other. In the direction of these diameters, then, there will be polarized axes too; the central line of edges of both sets, that is, the two transverse diameters, will be in a neutral state in the same way as the central plate of a compound magnetic bar is. The chromatic circles on the base of the ray will, therefore, be interrupted by two diagonals parallel to the two sets of edges, at right angles to each other; and in two diagonals forming angles of 45° with these, the chromatic development will be most vivid. But farther, these two sets of single rays and parallel edges must, in reference to each other, be in consecutive states; for we have already seen that transversion of edges implies a consecutive polarity, and, besides, whatever polarity one of them possesses, it will induce a consecutive state upon the other, and this must tend greatly to the unity and stability of the ray. A perfect ray of light then, however highly compounded, consists of two parts only, exquisitely decussating each other, and producing repose by the union of the mutual activities of its two parts. When one is affected, a corresponding state is induced upon the other, and the extent of the re-action is proportional to the quantity by which one is affected. They are positive and negative in reference to each other; and if we suppose any virtue or influence to be propagated along one of them, we must conceive another to be propagated along the other in an opposite direction.

There are two positions only in which these two parts of a perfect ray, simple or compounded, can exist in a state of repose, viz. where they run parallel to each other, as we have now supposed, or (were it possible to separate them) when one strikes off at right angles from the other. In the former case, the two parts neutralize each other, and the ray is simply a conductor of lumeniferous excitement. In the latter case, the one half, whose primitive direction is continued, acts equally on both sides of that which is now at right angles to it, determining it to this position, and retaining it in it. In the same way, too, magnetic bars may be laid parallel to each other, and they will remain in repose; but, supposing them to be square prisms, or prisms with bases at right angles to their axes, as the rays of light are, if one of them be disengaged from its cohesion at one pole, and that pole gradually lifted up from the other to which it formerly cohered, it will be found, that, when it is nearly in a vertical position, it starts to the vertical, and is retained there. In fact, a ray of light, by this bifurcation, again presents to us a model of the skeleton of a polarized solid. We may suppose a strong pencil of perfect light to have its exterior rays somehow or other thus separated at the middle into two parts, whose electricities are naturally consecutive, and whose edges are transverse. The central part of the pencil remains as an axis, and has nearly the same polarity at both poles. The branches which strike off at right angles represent the equator, cutting the axis at right angles, and are necessarily in a state of consecutive polarity.

Let A X (Fig. 26) be a pencil of perfect light, subjected to some action, by which its external rays are bifurcated, and one set is constituted at right angles to the other set. The single rays thus given off will constitute an equator or verticillus to the axis, and its polarity must evidently be consecutive to that of the axis, in as far as the axis is polarized.

When we consider the length of the sun-beams, the miscellaneous character of the light which must be emitted from so large a body as the sun, or even the facility which is afforded for such rays of light as are emitted to be reduced into the most perfect and symmetrical state before they reach the earth; if such a structure as that which has now been deduced from the laws of polarized action, and the structure of the radiant medium, anywhere exist, we will not deny it to the sun-beam. But we cannot place a sun-beam like a capillary crystal in the forceps of the microscope, so as to examine its structure, though its parts were large enough to be visible. As in most other cases of analysis, then, we must endeavour to discover its composition from the results obtained by its destruction. There can be no doubt, then, but the aggregation will be towards those rays which possess the greatest tension and excitement, and produce the greatest intervals; and which, therefore, in reference to the others, must be positive. The most highly positive tints in a solar ray will therefore lie towards the axis. Upon the destruction of the axis, in consequence of their greater directive force, they will be more difficultly bent from their original direction,—the intervals which they will produce will be the largest,—the heat which their percussion on cold bodies will excite must be greatest,—and the electric state, proper to the region where they are, will be positive.

Now, when a ray of the sun's light is made to fall upon a transparent dense medium, the plane on which it is incident being inclined to that from which it emerges, so that they meet in an edge, it is found that the emergent pencil possesses very different features from the incident one. The latter, when received on a white surface, in a dark chamber, formed a white circular image of the sun; but now, after it has been transmitted through the inclined surfaces and dense medium, or prism, the image formed upon the white ground is a circle drawn out in its equator, so as to constitute a parallelogram, terminated by semicircular ends. It is also no longer white in any region, provided the pencil be small, but painted with an infinite number of tints. Nearest to the position of the sun's image, which was formed of white light, without dissection, by the dense medium, is a full red; this is succeeded by orange, yellow, greenish-yellow, (passing into white as the pencil is enlarged), green, blue, indigo, violet. There are also other rays which bound this spectrum on both extremities, but they do not produce a colour visible to the human eye. Upon examining the spectrum with a delicate atomic electrometer, such as the chloride of silver, it is found that the violet, and deeply coloured end of the spectrum, is in a negative-electric state, and the red extremity in a positive state. On examining the calorific excitement of which its different parts are capable, by a delicate thermometer, it is found that the region which is most contiguous to the original direction of the ray, which possesses a fiery tint, and is electro-positive, excites the greatest heat; and on examining the magnitude of the radiant intervals by the method of interference, it is found that they gradually diminish from that which is reddest, hottest, and most highly electro-positive, to that which is darkest, coldest, and most strongly electro-negative.

These phenomena, which, on a general view, are exhibited in every experiment, whatever the dispersing medium may be, possess all the qualities that could be supposed to arise, in such a case, from submitting to the same treatment a sunbeam of the structure which has been assigned to it; and there is nothing in the solar spectrum which that structure does not account for. The tints are blended, and unequally expanded, according as the refracting medium acts most powerfully on light in one state or another; but the phenomena presented by oil of vitriol, and oil of cassia, two substances most dissimilar in their action upon light, possess such a general analogy with each other, that we may have great confidence in regarding the solar spectrum, not as the offspring of the medium through which the sunbeam is conducted, but of the structure of that beam itself.

But rays of light are not instituted by the sun only. Any body whatever, when its light is sufficiently developed by a due increase in its heat, becomes capable of instituting lumeniferous rays in the radiant medium round it. It cannot be expected that it shall, immediately on becoming luminous, be able to give origin to perfect compound rays, such as those of the sunbeam. As heat is the exciting cause, a positive tint may be most generally expected first, more especially as it will require great energy to overcome the quiescence of the surrounding medium, supposing the chamber dark, and still greater, to counteract movements occasioned by the sun in opposite directions. If a red tint appear first, then, as the heat of the body is urged, and particles of different temperatures or different states of vibration, each of them adequate to educe a colour, are developed, the inferior tints will gradually be added to the red, which naturally forms the axis; and the artificial light, in the perfection of its structure, may ultimately emulate the sunbeam itself, in which it will be much aided by induction, and the lateral transmission of polarity. But if the first rays which the luminous body institutes be not red, but some inferior tint, as for instance yellow, then to this as the axis, the colours inferior to yellow will be successively added as the quantity of colour emitted becomes greater; and without a great change in the character of the rays, red and orange are excluded from the light, which, on analysis, will, therefore, if the temperature be sustained uniform with that at which the yellow rays were instituted, yield homogeneous yellow light; or, if not then yellow, with blue and more highly negative tints, but without any red or orange. These deductions are in harmony with the experimental results of Dr Brewster, in his researches with a view to discover a monochromatic lamp, for microscopical observations.*

The mode of atomic movement of greatest symmetry, in a medium composed of, or containing compound perfect rays of light, and that in which the re-action of the variously coloured rays and the quiescent parts, can do the least in bringing the moving parts to rest by interference, is, when every part acts so that the radii of the prism, or white ray, continued from the axis through each colour outwards, to a quiescent point beyond the ray, are moved upwards and downwards with the axis, their peripheral extremity being at rest. According to this view, while in a state of combination in the sunbeam, the vibrations of all the colours would be isochronous, and their amplitudes would diminish from the axis to the point of quiescence, in the same ratio as their distance. In such a state of movement, there can be no interference, either between the different parts of the same, or between contiguous rays. Supposing two contiguous white rays to be in opposite movements of the parallel laminæ at the same time, the intermediate point between them will merely be the fulcrum; and the radii on each side will act as if they constituted one lever moved to and fro round its fulcrum in the centre like a balance. When, again, the parallel laminæ of the two white rays are both in systole, or both in diastole, at the same instant, the radii on both sides move like a hinge. But it is to be remarked of this region contained between the axes of two contiguous rays of white light, that any symmetrical portion of it possesses the regular polarization of a solid. Thus, both axes of the rays which now become poles are in the same state, which, in this case, happens to be positive; the middle or quiescent region, again, is negative or consecutive to the polar, as the equatorial region ought to be. Hence, the transverse polarity in this direction will operate in causing contiguous sunbeams to move synchronously. Upon the whole, were we able to understand it, and as far as we are able to see into it, the sunbeam seems to be the most perfect and beautiful piece of mechanism in nature.

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* Edin. Trans. vol. ix.

The amplitudes of the vibratory excursions of the different molecules in the transverse section of a ray of white light, to which we have supposed them constrained by the law of symmetry, are well suited to the intensity of their polarity; and when the symmetry of the ray is destroyed, and the light becomes coloured according to the regions of the sunbeam, of which the coloured rays are merely a continuation, it is very reasonable to believe that the amplitude of the excursions of the molecules remains the same as before; but that, according as these are less, a greater number of radiant molecules propagating the coloured light is involved in the same length of ray. Hence it follows, that their intervals must also become less; and, therefore, if these views be sound, it ought to be that the intervals of the radiant molecules conducting different colours, ought to be different, those of red light the greatest, of all the tints visible to our eyes, those of violet the least, (taking for granted that such a tint exists in the sunbeam); and there ought to be a common difference in the magnitude of these intervals, when the colours have been propagated from points in the solar ray, equidistant from each other. It has been already shown, that, by observing the lines of interference, the intervals of the molecules may be calculated; and as these interferences equally take place in all colours, the intervals may be ascertained for all sorts of light. They have been calculated for the principal tints, by M. Fraunhofer, whose experiments have revealed far more of the intimate structure and admirable symmetry of the sunbeam, than those of any other man. According to him, the interval for red light is ·00002582 of an English inch, while that for violet is ·00001572. Between these two, there are three principal tints, orange-yellow, green, and blue with indigo.

If, then, we form a series of five terms in arithmetical progression, these being the extremes, we shall obtain intervals corresponding to the tints, at equal distances from the axis of the sunbeam. Such a series, as nearly as need be cared for, gives the first of the following series of numbers, which are contrasted with those deduced by Fraunhofer for the tints opposite to them:—

·00002582	·00002582	Red.
·00002329	·00002319	Orange Yellow.
·00002077	·00002073	Green.
·00001825	·0000 { 1912 1692	Blue. Indigo.
·00001572	·00001572	Violet.

The fourth term, were the blue and indigo consolidated, would evidently lie a little, from the mean position between blue and indigo, on the side of the former. It appears, then, as nearly as experiment and the hazard of fixing upon the tints could be expected to permit, that the five principal tints of the solar spectrum are derived from hollow cylinders of radiant atoms, concentric with the axis of the sunbeam, and equidistant from each other.

If it be so, there ought to be a great excess of the negative tints, blue and violet, in the production of which, a much greater quantity of radiant matter must be involved than in those tints which lie nearer the axis. It is very reasonable to expect that the two extremes of the chromatic axis, those regions beyond the violet on the one hand, and towards the axis, or within the red, on the other, should not produce vision, partly from the extreme state of their vibrations, and partly from their highly unipolar state. That which must be best fitted for vision, is the intermediate region, which, in as far as the structure of the ray is concerned, is left in the same state of polarity as it has derived from the luminous body which excites it; and, accordingly, a region nearer the red than the violet, as we should expect, if the negative colours were most abundant, is found to possess a power of illumination far greater than either extremes, and the curve expressive of the force of darkness in the spectrum, extended towards the poles from the point of greatest illumination, would have the same aspect as that towards the poles of a magnetic bar from its neutral region, which expresses the increase of its magnetic force.

As indicative of the excess of green, blue, indigo, and violet, in the sunbeam, we may remark the great abundance of these tints, and colours compounded of them in nature, compared with the more central tints. The ocean and the sky are blue. The earth, covered with vegetation, is green, becoming blue in the distance. The soil is usually more or less black. Bright colours are confined to animals, blossoms, the tints of the evening sky, (where there is, however, always a due proportion of negative tints), the peroxide of iron, and matter comparatively rare, or in peculiar states. We have no power of expanding the sunbeam in a due proportion by the prism, so that the spaces between the individual rays shall always be equal. Were we able to effect this, the relative quantity of negative and positive colours might be measured. It is to be remarked, however, that the more perfectly any substance disperses light, the more completely does it expand the negative tints, in relation to the positive. Another circumstance intimating the great density of the negative rays, compared with the positive, in the spectrum formed by a glass prism, is the comparatively vast number of interferences which occur in the former. There are various circumstances, indeed, which conduce to this effect, but the dark bands (which, it will be afterwards shewn, are merely lines of interference) in the spectrum of Fraunhofer, are ten times more numerous on the negative than the positive side; and, to account for this, it seems necessary to suppose that the density of the rays on that side is much greater. The colours there are also very vivid, and, notwithstanding their softness and approximation to the colour of the retina and pigment, they fill the eye very perfectly. If we suppose that four perfect rays in the centre of a white ray (involving the axis and the crossings of the neutral axes) are deprived of colour, transmitting light of the true quality, developed on the surface of the luminous body, or none at all, and that each of the five principal tints is produced by a hollow square prism, the breadth of whose wall is one perfect ray, then the number of rays of light involved in producing the different colours will be in the ratio of the odd numbers, unity representing the colourless central square, so that the quantity of the positive light including red, orange, and yellow, is to the quantity of negative colour, including green, blue, indigo, and violet, as $2_3 : 3_3$. At all events, whatever quantity of uncoloured matter we suppose in the axis, the extent of negative surface must be greater than of positive; an arrangement which, it has been already found in galvanic combinations, gives rise to the most vigorous excitement, and which may be observed in a multitude of cases of atomic chemical union.

A sunbeam, then, or ray of white light, is, as Newton said, "in some sense a hard body," and its structure is not different from other symmetrical tissues, whose cohesion may admit of their being handled as crystalline masses. We shall now proceed to examine the phenomena of its ethereal cleavage.

OF THE REFLECTION OF LIGHT.

WHEN the symmetry and continuity of a pencil of light, vertically incident, is interrupted by some intercepting medium, (which must itself be, in every case, composed of radiant atoms in a state of greater or less compactness and condensation,) it must either be continued through that medium, or be stifled and lost in its substance. But if the perfect ray be incident any how at an oblique angle, phenomena more easily traced must ensue. The surface of every body in some state of aggregation, may be regarded as covered with a stratum of light. Upon this stratum, then, the ray of light constituted in the radiant medium is incident obliquely; and if it had it not before, it must assume that position in which the plane of one of the neutral axes of the ray is perpendicular to the surface illuminated. For the tendency of the ray is to proceed in a straight line, and the extremity of a neutral axis (of which it has been shewn there are two in the base of every perfect ethereal ray, or ray constituted in the radiant medium,) being less highly excited than other places, will be repelled less by the stratum of light proper to the surface, and suffered to penetrate deeper. But on both sides of this neutral axis, (or rather base of a neutral plane traversing the ray longitudinally, and including the axis of the ray or radiant prism,) its farther penetration is prevented by an equal force; it will, therefore, be kept there, in a position such that the plane of one of its neutral axes is perpendicular to the intercepting plane. This is the only position in which the edges of the incident light are symmetrically related to the medium beneath, and every cause must conspire to produce this arrangement. Such, then, at the surfaces of most substances, will be the first change which a perfect ray of light will undergo. Now, it is to be remarked, that half the ray is incident upon the intercepting plane, with all its edges most favourably placed for being continued, or for penetrating the medium, while the edges of the other half are parallel to the intercepting plane, and best fitted for being continued into the radiant medium back again, so as, by a reflected ray, to give rise to a reproduction and image of the incident ray. Only one half of the ray is axifrangible in the plane of incidence. Hence, a part of the lumeniferous excitement propagated along the incident ray, ought to penetrate the medium, and be stifled and lost, or conducted through it, and another part ought to be continued up again into the radiant medium, constituting a reflected ray of light, so as to be an image of that part of the incident light which has not penetrated the medium, or been occupied otherwise; and the quantity of light reflected compared with that transmitted, must evidently increase with the obliquity of incidence; for at angles near the vertical, even those rays whose edges are incident parallel to the surface, are more contiguous to the atoms of the dense medium than to the atoms in the radiant medium on the same side of the reflecting plane, and communicate their lumeniferous excitement in a course more or less straight. At angles of great obliquity, on the other hand, all the rays are best fitted for being transmitted back to the radiant medium, which far above all others gives facility to the propagation of light.

It might certainly be expected, however, that at some angle of inclination between the perpendicular and that where total reflection takes place, a symmetrical distribution of the two parts of a perfect ray already described might be instituted, in which the perfect pencil shall give off rays of one polarity, at right angles to the part of the pencil which is continued through the medium. It is found that this is the case. The phenomenon was discovered by M. Malus, and the discovery, like that of Volta, puts in the possession of the crystallographer, a photo-motive instrument of analysis, not less powerful, in reference to crystalline structures, than the electro-motive apparatus is in reference to chemical structures. In the latter, by separating a medium which is in a state of electric neutrality into two parts, one powerfully electro-positive, the other powerfully electro-negative, and conducting to a convenient place the excited unipolar fluids, we become possessed of a region of intense excitement, either of positive or negative electricities; and molecules, held by chemical union, when introduced into these regions, have the equilibrium of their electrical state subverted, and they are changed or torn asunder. In the same way, by reflecting at the proper angle, a pencil of natural light, which is, previous to reflection, in a quiescent and mild state, the opposite polarities of its two transverse parts retaining each other in a state of neutralization, it is separated into two, one of which is reflected into a convenient region in an unipolar state, and the light of molecular bodies having an individual polarity when introduced into it, have their chromatic polarity exalted in a very admirable manner, as will be touched upon afterwards.

But besides its state of unneutralized excitement, light thus reflected must evidently possess properties very different from perfect or common light; for all the edges of the binate molecules of which it consists are parallel to each other, while in common light there is an equal number parallel and transverse. The whole of the reflected pencil, then, when incident at such an angle that the reflected part may strike off at the right angle from the transmitted part, is in the state of single rays, which are in parallel positions, and merely images of each other. In relation, then, to its origin and properties, as well as its nature, it may be called *singled* *unipolar*, or, as usual, *polarized light*. Light singled by reflection, must always have the poles or edges of its molecules parallel to the reflecting plane, and transverse to the plane passing through the incident and reflected pencil or the plane of reflection, in which it is commonly said to be polarized. We shall attain an easily conceivable idea of the properties arising out of the structure of singled light, by viewing a ray simply as a crystalline prism. It appears, then, that, along the whole of its length it is axifrangible, or may be reflected in the plane in which it has been generated: in a plane at right angles to this, on the other hand, it is quite rigid, and will not suffer reflection; and between these two planes, its symmetry will yield more or less to the force which is applied to break it, according as that force acts more or less powerfully upon the parallel edges of the binate molecules of which it consists. Suppose, then, that a sunbeam, when the sun happens to have an altitude of 37° 6′ 12″, is admitted into a dark chamber, it will be found, on applying an instrument of cleavage to it, such as a plate of glass, or any polished surface, that it may be partially reflected in equal quantity in any direction, when the reflecting surface is applied to the axis of the ray at the same degree of obliquity. The sunbeam is natural and perfect, composed of a number of illuminated molecules, with their edges in equal numbers, in transverse positions: if one part be reflected in one direction, then another part is equally fit to yield a reflection in a direction at right angles to the first. But let the sunbeam now fall upon a surface of stagnating water. The angle which has been mentioned is deduced from the atomic structure of water to be that inclination at which it singles light completely, and it differs from the experimental result only a few minutes. The reflected part of the sunbeam will, therefore, be completely singled; and we are in possession of such a prism as we wish, to examine. All the edges of the lumeniferous molecules must be parallel to the surface of the water, and to a line joining his two eyes, supposing the observer to stand in the same plane with the aperture which admits the sunbeam, and the vessel of water. The pencil is therefore axifrangible in this plane, and will not refuse to be reflected in the direction of the window. Accordingly, on applying a plate of glass to the ray, a bright spot of sunshine may be driven up and down in this plane, according to the angle which the plate of glass used for reflection makes with the axis of the singled pencil to which it is applied. But let the prism of singled light be tested in a direction transverse to the window and water; as often as the angle at which the glass is applied to the ray is the singling angle of that medium, the ray refuses to yield. There is no bright spot upon the wall. All the lumeniferous excitement propagated along the single prism of radiant matter, has entered this plate of glass. It is placed in a position fitted for inducing total transmission. The ray is not frangible in that direction. The result is the same whether it be tested by the glass-plate on the right hand or the left. The prism of lumeniferous atoms is symmetrical on both the sides that are opposite to each other. If, then, the glass plate (being always inclined to the ray at its singling angle) be brought to its first position, so as to give a bright reflected spot in the plane in which the singled light has been generated, and gradually moved round the singled ray, the intensity of the bright spot will be seen to fall gradually away, until, in a plane transverse to that from which it set out, no light is reflected at all. Continuing the revolution, reflected light appears again, and increases in intensity, till, projected on the floor in the same plane as the aperture and the water, it is as bright as it was on the window-shutter. Continuing the revolution, the reflection decays again, till it vanishes in the point opposite to that where it vanished before in the first half of its revolution; after this, it increases till it arrives at its former intensity on the window-shutter. If then the observer stand fronting the radiant aperture, and in the same plane with it and the singling surface, the singled light may be reflected in the direction of his face or back, but not on his right hand or left. The singled lumeniferous prism of radiant matter may be broken in the former plane, but not in the latter. Many other substances besides a vessel of water may be used. A plate of glass, or what is better, a number of plates laid above each other, the shining surface of a table, a marble-slab, any thing that reflects and has not a very intense reflective power at one angle of inclination or other, will be found to single the light incident upon it; and these very striking phenomena may be observed with the greatest ease. The light which comes from the azure of the sky, as will afterwards be more particularly stated, is completely singled in certain regions of the canopy; and all the tints of the rainbow are in the same predicament. It is a curious experiment to present a Claud Lorraine glass or nonmetallic reflector, so as to form an image of a landscape, over which there is a rainbow. As often as it is inclined to the rainbow at the singling angle, the bow, however vivid, vanishes, while the other part of the landscape remains equally bright.

There are many other phenomena of great interest presented by singled light, of which those connected with its interference are not the least. Interference, or the arresting of the propagation of lumeniferous excitement, has already been ascribed to the simultaneous incidence of two molecules of light in consecutive states upon a third, which forms a part of both rays, whereby it is left quiescent and neutral, the opposite electricities simultaneously communicated, failing to induce a state of illuminated polarity upon it. Hence two rays singled with their edges transverse, or in rectangular planes, cannot interfere, whatever be the length of their routes, because in the whole course of the rays, there are no molecules of radiant matter, engaged or common to both. The rays decussate each other, each sustaining the excitement of its own molecules, and the region containing the two singled rays makes an approach more or less near to the state of common light.

Portions of the same singled pencil, however, must interfere with each other, as common light does. Where the rays decussate, there are common molecules, which, when the differences of the lengths of the rays are half an interval, are just as in the case of common light, exposed to the induction of opposite states at the same instant, and therefore must remain unilluminated. Nor does it make any difference how often soever one of the two parts of the pencil, originally singled in the same plane, may have been transversed, provided the first and last directions be parallel. But when the two singled pencils exposed to interference consist of the consecutive parts of a perfect pencil, or those which are naturally in consecutive states and a transverse position, they have not been yet made to interfere in any experiment, though they enter upon the crossing in parallel positions, or singled in the same plane. It is difficult to conceive that two rays could be mingled in consecutive states, without acting as transversing piles (polarizing piles) upon each other. A ray of light, one part of which was in a state consecutive to the other, and yet all the edges parallel, would be in an anomalous condition, in which it might be inferred, that the induction derived from the molecules coming up behind could not sustain it; and if the pencils were equal, it seems probable that the edges of both the parts, which are interlaced, shall have moved round through 45°.

The immediate effect of the illumination of objects by reflection, is to render them visible, and their splendour depends on the quantity of light which rises up from them. Their colours will be noticed afterwards.

OF THE TRANSMISSION OF LIGHT.

Like the metals in reference to electricity, and soft iron in reference to magnetism, many bodies conduct light through them in a very passive manner. Others, again, like electric and magnetic substances, have a lumeniferous polarity induced upon them, and present phenomena of great curiosity. Those which reflect lumeniferous excitement very intensely seem to be almost impenetrable to it; and an incident ray has not directive force enough to be constituted in their substance, but with greater facility gives off its excitement to the radiant medium on the same side of the reflecting surface, and constitutes a reflected ray. To this class the metals belong, which, except in the äeriform state, become eminently illuminated on the surface, but do not permit a ray of light, even vertically incident, to be propagated into their substance to any considerable depth. Others, again, such as the diamond, are of an intermediate character. When the ray of light is incident near the vertical, they permit a part to pass through them, but when the obliquity increases to a certain amount, they become wholly opaque to the ray, and reflect all the light incident, which is not occupied in sustaining the illumination of their surfaces, or destroyed there. The condition of structure most favourable to the conduction or passive transmission of light, is a symmetrical arrangement of the particles of the mass, the want of individuality of molecular form, and of an intense sphere of free light investing the particles.

Aëriform media are invariably more or less transparent; but it is probable that, in many cases, the light is not conducted through the radiant atoms implicated in their composition, but simply by the radiant medium with which they are interlaced, and that, if we could exclude this medium, and prevent its rising along with them, many gases would not only be highly coloured, but absolutely opaque. It is difficult to conceive how such an aëriform medium, as a volume of hydriodic acid, which is colourless and limpid, could conduct light otherwise than by the radiant matter existing between its particles. These are twice as distant as those of common air, or hydrogen gas; yet every particle seems to be about eighty times the weight of one of the latter, which must be accompanied with such a resistance to motion as would not admit of those systoles and diastoles which, in so rare a medium, would be necessary for the conduction of light through it.

The liquid state seems most favourable for the conduction of light; for, while the particles are almost as densely arranged as in solids, in some cases more so, they are not in that molecular state and polarized arrangement which, when light is incident upon it, produces polarized excitement and an irregular action upon the transverse rays in a pencil of common light. Accordingly, it is found that liquids, even when sensibly coloured throughout their mass, conduct luminiferous rays through a great breadth. Along with liquids may be classed bodies in the gelatinous state, and vitreous substances of uniform density throughout.

But even through liquids and such bodies, a ray of light, except when vertically incident, is not transmitted in a straight line, continuous with that of the ray previous to incidence. In every case where a pencil of light produces the illumination of a surface, a force must, by that act, be developed to change its direction. The illuminated spot is, in fact, a congeries of atoms of radiant matter invested with light. In the medium, on the surface of which the illuminated spot is developed, the atoms continue to be so dense that the illuminated state penetrates to some depth; and, therefore, the light proper to the atomic matter, of which the superficial stratum of a dense medium is composed, continues while that stratum continues to be illuminated, in a state of vertical pulsation, or progression and recession, in the direction of an axis, to which the plane of the surface is the equator. When an ethereal ray of light is incident, parallel to this nascent vertical ray, or perpendicular to the illuminated surface, there is no reason, in as far as the vertical "motion or moving thing" is concerned, why it may not proceed in a straight line. The ray excited at the surface of the medium conspires with the ethereal ray to sustain a vertical direction through the dense medium, and in this case the quantity of lumeniferous excitement propagated through that medium must be a maximum. But when an ethereal ray is incident obliquely, it can only happen that the oblique propagation of excitement, crossed by the lines of vertical propagation, must suffer a deflection from its previous course towards that in which the vertical action takes place.

On entering a dense medium, then, a ray of light must be refracted towards the perpendicular, because the vertical propagation is right downwards; but on leaving a dense medium, it must be refracted from the perpendicular, because, in that case, the propagation from the illuminated spot is right upwards.

This is a refracting apparatus, exactly analogous to that assumed by Newton, to account for the constant ratio of the sines of incidence and refraction ; and were the motion of this "moving thing" and that of the incident ray, to suffer no modifications from the arrangement of the atomic matter of the surface, there can be no doubt but the amount of the angle of refraction, as measured by its sine, would vary accurately with that of incidence, as measured by its sine. It is probable, that in nature, however, there is often only an approximation to the fulfilment of this general expression ; that there are minute departures from it at certain inclinations, which, if accurately observed, would be most instructive as to the structure of the surfaces of different bodies. The fashion too prevalent in experimental philosophy, in our day, of disregarding all small differences yielded by experiment, and of working the same experiment over and over again, with more or less care, seeking for a mean which shall correspond with some pre-conceived formula, cannot be too much regretted ; and, after all, such formulæ often illustrate the subject discussed much less than they do the mathematical talent of him who constructs them.

As this work pretends to enable us to pourtray the intimate structure of the surfaces of refracting bodies, the subject of refraction need not now be investigated further in general terms. Its quantity depends upon the quantity of light proper to the illuminated surface, and upon the tension or directive force of the incident ray or its parts. The phenomenon may be thus conceived. Let P P′ (Fig. 27) be the plane surface of any refracting medium more dense than the radiant, and I O the axis of any ray of light incident upon it, at any oblique inclination. The dense surface under that ray is immediately illuminated, and this illumination implies a more or less powerful pulsation downwards of its light, immediately after the most contiguous molecule of the ethereal ray has impinged towards it. The nature of subtile matter induces us to believe that the form of the congeries of atoms implicated in the composition of the refracting surface in which this pulsation takes place, is hemispherical, the axis of the illuminating ethereal ray incident impinging on the centre of the hemisphere. Were the rectilineal progression of this ray not interrupted, the length of the pulsation to which the ray would give rise, in any one movement, reckoned from the point O, would be the same whatever was the direction of the ray, and in the course of incidence. Nor will the case be different on entering another medium, provided, like the radiant, that medium have an uniform structure; therefore, the pulses propagated by the incident ray, in the dense medium, in the course of incidence, will be represented by the radii of a circle, when the incident ray is moved upwards and downwards in the same plane. But, while a pulse is propagated by the incident ray through the radius, with more or less directive force, another is simultaneously propagated from the surface, through the sine corresponding to that radius. The polarity of the pulses being developed only at the moment when the movement is at zero, the pulse, in the course of incidence, will pass through the larger sines without interference. But, at the point i, two polarities are simultaneously generated, whose force and direction, supposing the directive force of both equal, are represented by $o\ i$ and $s\ i$. The ray which is to be continued through the medium, then, will be the resultant of these, or that in which an ivory ball would run, if struck simultaneously by two coming in the directions of $o\ i$ and $s\ i$, and with forces proportional to these lines. Let O R′ be drawn parallel to R i, and let $s'\ r$, the sine of its inclination to P P′, be drawn. It is evident that $s'\ r$ always varies in the same ratio as $s\ s''$, or its half $s\ i$. But $s'\ r$ is the sine of inclination of the refracted ray, and $s\ i$ that of the same ray incident; or they are the cosines of the angles of incidence and refraction, and these being in a constant ratio, so also must be their sines, as commonly stated. To account for different refractive powers in different media at the same incidence, we have only to suppose, that the illuminated hemispheres, in different substances, according to their intensity, diminish more or less the directive energy of the ray propagated in the course of incidence, which has to penetrate them, while the directive energy of their own ver-

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As this work pretends to enable us to pourtray the intimate structure of the surfaces of refracting bodies, the subject of refraction need not now be investigated further in general terms. Its quantity depends upon the quantity of light proper to the illuminated surface, and upon the tension or directive force of the incident ray or its parts. The phenomenon may be thus conceived. Let P P′ (Fig. 27) be the plane surface of any refracting medium more dense than the radiant, and I O the axis of any ray of light incident upon it, at any oblique inclination. The dense surface under that ray is immediately illuminated, and this illumination implies a more or less powerful pulsation downwards of its light, immediately after the most contiguous molecule of the ethereal ray has impinged towards it. The nature of subtile matter induces us to believe that the form of the congeries of atoms implicated in the composition of the refracting surface in which this pulsation takes place, is hemispherical, the axis of the illuminating ethereal ray incident impinging on the centre of the hemisphere. Were the rectilineal progression of this ray not interrupted, the length of the pulsation to which the ray would give rise, in any one movement, reckoned from the point O, would be the same whatever was the direction of the ray, and in the course of incidence. Nor will the case be different on entering another medium, provided, like the radiant, that medium have an uniform structure; therefore, the pulses propagated by the incident ray, in the dense medium, in the course of incidence, will be represented by the radii of a circle, when the incident ray is moved upwards and downwards in the same plane. But, while a pulse is propagated by the incident ray through the radius, with more or less directive force, another is simultaneously propagated from the surface, through the sine corresponding to that radius. The polarity of the pulses being developed only at the moment when the movement is at zero, the pulse, in the course of incidence, will pass through the larger sines without interference. But, at the point *i*, two polarities are simultaneously generated, whose force and direction, supposing the directive force of both equal, are represented by *o i* and *s i*. The ray which is to be continued through the medium, then, will be the resultant of these, or that in which an ivory ball would run, if struck simultaneously by two coming in the directions of *o i* and *s i*, and with forces proportional to these lines. Let O R′ be drawn parallel to R *i*, and let *s′ r*, the sine of its inclination to P P′, be drawn. It is evident that *s′ r* always varies in the same ratio as *s s″*, or its half *s i*. But *s′ r* is the sine of inclination of the refracted ray, and *s i* that of the same ray incident; or they are the cosines of the angles of incidence and refraction, and these being in a constant ratio, so also must be their sines, as commonly stated. To account for different refractive powers in different media at the same incidence, we have only to suppose, that the illuminated hemispheres, in different substances, according to their intensity, diminish more or less the directive energy of the ray propagated in the course of incidence, which has to penetrate them, while the directive energy of their own verdense laminæ of the same substance, provided some singled light be reflected at the first, the pencil ultimately emergent, will be completely singled also, the plane of its edges being of course transverse to that which is obtained by reflection of the same pencil. Thus, when receiving a pencil of common light upon a number of parallel plates of glass at the singling angle, by reflection from the first surface, a considerable pencil may be obtained completely singled in one plane; and, by transmission through a greater or less number, a considerable pencil may be obtained, completely singled in a transverse plane. Let R (Fig. 28) be a perfect pencil, incident at the singling angle upon the surface of the photomotive pile A B, a part of the excitement rises up in the direction of R′, singled with the edges of the molecules transverse to the plane of incidence and reflection, or parallel to the reflecting surface. A singling action goes on at the illuminated surfaces of the successive plates, and the pencil R″ is completely singled, the edges being in the plane of incidence and reflection, or transverse to those of R′. These two singled pencils correspond to the two wires of an electro-motive pile.

OF DOUBLE REFRACTION.

Such are some of the most obvious phenomena produced by lumeniferous excitement, when propagated, transmitted, or conducted through media, which have not a specific polarity of their own, and which, during transmission, act equally upon both the parts of which a pencil of common light consists. The transmitted pencil may simply be regarded as the prolongation of the incident pencil, refracted and mutilated at the surface of the dense medium, according to circumstances. But when the refracting medium consists of molecules symmetrically disposed in it, each having a specific polarity of its own, it will readily be inferred, that the different parts of a ray of light will be differently affected, when they come in contact with the polarized molecules. To give rise to a molecule possessed of free polarity, it is only necessary that its form deviate from the spheroidal or polygonal tessular; (17). If there be an excess either of equatorial or polar parts, it becomes possessed of an excess either of negative or positive polarity, and such a state being in different degrees of intensity in different regions of the molecule, the lumeniferous excitement will be constituted in the medium in two directions, which must, of course, be possessed of consecutive polarities. A polarized medium cannot admit a body, neutral by consisting of two polarized parts neutralizing each other, to pass through it, or exist in it. As between the voltaic poles, potash is separated into oxygen and potassium, or water into oxygen and hydrogen, so, by a symmetrical pile of polarized molecules, a ray of light is separated into two, and made to conform in the state of its polarity, and, consequently its position, to the demands of the pile. The action of a doubly refracted crystal cannot be regarded as a mechanical splitting or diffracting into parts an incident ray. It is a new organization of the lumeniferous excitement, conformable to the medium in which it must exist. Instead of attempting any thing like a delineation of the movements of the subtile matter, by which this new distribution of lumeniferous excitement is effected, which may be done once for all, when the molecules of some doubly refractive crystals shall have been constructed, or imagining geometrical constructions to explain the phenomena, which has been well enough done already, it may only be remarked, in general, that, when a perfect ray of light is incident upon a polarized pile of molecules, except in the direction of the axes of no polarization of the molecules, two rays are instituted instead of one, as obtains in the radiant and other tessular media, consecutive to each other, and, consequently, at their emerging into the radiant medium again, two ethereal rays are developed, the edges of the molecules being in transverse planes. One of these rays may be regarded as the atomic or ordinary, and the other the molecular, unusual, or extraordinary. The direction of the atomic ray is always determined by the direction of the original ray, and the action of the illuminated atomic hemisphere, which has been already conceived and explained. The direction of the molecular ray is determined, not by its relation to the surface on which it happens to be incident (which is the equator of the atomic refracting movement,) but to the equator of the molecule.

Both the rays, like those in a perfect ray of radiant matter, are equal in quantity; and like them, also, they are of consecutive polarity, and must therefore develope rays in the radiant medium, singled in opposite planes. The atomic or ordinary ray (though it is to be remembered, that it is ordinary only in as far as its refractions obey the ordinary law of the sines) gives rise to a ray in the radiant medium on the emergent side, having its edges in the same direction as if it had been singled by reflection. The molecular, or extraordinary ray, gives rise to an ethereal ray, having its edges singled as if by transmission through a singling pile; and this ray is found upon either side of the other, in the plane of the axes of the crystalline molecules, according as the external current in these is from the equator to the poles, or from the poles to the equator (figs. 19 and 20). The plane of the edges of one of the rays is always parallel to the equator of the crystalline molecules; of the other, to the axis. The bifurcation, consequently, always takes place in the plane of the axis, which is named the principal section of the pile or crystal.

All crystalline bodies which are destitute of tessular forms, present in a greater or less degree the phenomena which have now been noticed: and on tessular crystals, and transparent masses not possessing individuality of form, they may be induced by changing the condition of the matter in different parts, as by temperature or compression. In no body, however, are they exhibited so eminently as in calcareous spar or the carbonate of lime. This beautiful mineral occurs crystallized in hundreds of different forms; but all the forms, when broken down, yield fragments which are all similar, being rhomboids with angles of 105° 5′ and 74° 55″, the exact dimensions depending on the temperature in which they are examined. As the heat is raised, they approximate the tessular form, in consequence of the diminution of the cohesion (which caused a deviation from the tessular), and an exhilaration of electricity, which tends to develope the tessular series. The axis of such a rhomboidal fragment is the line joining the symmetrical angles. When a pencil of common light is incident in any manner upon the natural face of such a rhomboid, it is remarked, that two immediately make their appearance in the crystalline medium, both of which always traverse the axis; so that, in whatever way the crystal is turned about, they sympathise with the motion, and are always constituted in a plane which contains the axis and the short diagonals of the opposite faces, that is, in the principal section. Even when the ray is incident vertically on any of the natural faces of the rhomboid, two make their appearance in the crystal, one of which, the atomic, ordinary, or normal, is not solicited from the vertical by any force, and proceeds without refraction; the other is drawn away from the axis, as if by a current sweeping it towards that pole to which it is already most contiguous. If any number of rays be incident, however much scattered and confused, those developed in the spar are all reduced to parallel planes, which are so many principal sections of rhomboids smaller than the mass, in a parallel position, and involved as parts of the whole. On whatever side of the rhomboid the incident light is applied, the success is the same. As rays of light can only be constituted in particular ways in the radiant medium, which depend on its structure and polarity, so, in this crystal they are developed according to its specific structure. When the incident ray is vertical, the two constituted in the crystal contain an angle of 6° 12′; so that, even in a small mass, the remarkable phenomenon is very obvious. If, however, the symmetrical or obtuse angles be polished away, or other means taken for constituting a pencil parallel to the axis, a vertical ray gives no double refraction; and the same happens if a vertical ray be sent upon a plane, found by cutting away two opposite lateral edges, and replacing them by transparent surfaces parallel to the axis. But in these directions, in which the axis and the equator of the molecule are discovered, when the incident ray is not perpendicular to the refracting surface, and in all other positions, two rays appear separated by a larger or smaller angle.

If now we recur to the apparatus formerly suggested, when illustrating the singling of light, and cause the sunbeam, instead of falling directly upon the surface of the water at the singling angle, first to traverse such a rhomboid, whose principal section is in the plane of incidence, it will be found that the atomic ray, or that which obeys the ordinary law of refraction, is readily reflected from the surface of the water, while the other penetrates it entirely. The extraordinary ray, then, has the edges of its molecules parallel to the axis of the rhomboid or its molecules, the ordinary ray to the equator of the molecules.

When the rays that have thus been developed in one rhomboid are received upon a second, the phenomena which ensue depend upon the position of the latter. When the principal sections of both are parallel, no change in the structure of either of the rays is produced. They are already shaped for transmission. They are only separated farther, and to the same amount, as if they had penetrated one rhomboid equal in thickness to both. Nor does it make any difference though the lumeniferous excitement may have been conducted through a considerable breadth of radiant matter lying between the rhomboids; for of all transparent media, the radiant matter is the most passive conductor of a symmetrical ray of light. If one of the rhomboids be now inverted upon the other, so that their principal sections are still parallel, but their axes form a zigzag line, the structure of the two rays remains the same, but the second rhomboid, if of the same magnitude as the first, brings them to an incidence again; and thus a prism of calcareous spar may be constructed of any depth, consisting of intervals of no double refraction, and half intervals of double refraction. When the second rhomboid is placed so that its principal section is at right angles to that of the first, it is necessary for each ray emerging from the first, that it may continue its former position in the molecules, now placed in tranverse positions, to have its edges transversed (viewing it as an ethereal ray); and so on, rhomboid after rhomboid, the same ray is always found with its edges parallel to the equator, and the other parallel to the axis of the molecule or the axis of the rhomboid. Did this transversing not take place, the polarity of the ray would be changed at each transmission.

In the quadrants between the parallel and rectangular positions of the principal sections, each of the single rays gives rise to two which pursue the only paths by which they can be transmitted in such a medium. Their quantity is equal when the principal sections are inclined at an angle of 45°, and at other angles that predominates, which is conformed most easily to the equator or axis most contiguous to the incident ray. Thus, by means of two rhomboids, a pencil of common light becomes the origin of four; but by means of one only, it may give rise to no fewer than seven, as has been shown by M. Malus, and this will serve to illustrate all the phenomena.

Let there be a rhomboid of calcareous spar, fig. 29., whose axis is AB, and let a pencil of common light be incident at *b*, and not in the plane of the principal section, part of it will be reflected in the direction *b m*. Two *b e* and *b e'* will be constituted in the principal section of the crystal, and, except at a certain angle, each of these will give rise to three, one in the radiant *e e* and *e' e'*, and two reflected back into the crystal, which enter the radiant at the superior surface. If the singled pencils traverse the rhomboid at such an angle that they both fall upon the inferior surface at the singling angle, which, however, cannot be accurately the case, then the molecular or extraordinary ray becomes wholly emergent, being incapable of reflection.

The circumstance, that these two singled pencils have different directions, one proceeding in a course more favourable for deep transmission than the other, brings it to pass sometimes, that one of the singled pencils is stifled and lost long before the other, so that a plate of the singling substance remains pretty transparent, while it ultimately transmits a ray singled only in one plane, as if it were a pile of glass plates, as in (Fig. 28). This is the case with agate and other substances, but none possesses this property more remarkably than the coloured varieties of the tourmaline, which renders

Whether it be capable of indicating a violet colour, or a yellow, by looking upon the path of the ray we cannot tell; in all cases the ether remains perfectly limpid. But a white body terminating it, or illuminated by it, will immediately shew the mean or resultant colour of the light by which it is illuminated; for it has no power of acting irregularly upon the incident light, but sustains or reflects as many rays of one colour as it does of another; and, consequently, by its tint permits the nature of the incident light to be announced in the eye as faithfully as if it had not suffered reflection. If, then, we have any means of separating a pencil of white light into its constituent rays, a white body placed to receive its parts will, by its colours in different regions, indicate the constitution of white light faithfully.

Now, it is a very easy matter thus to separate a common sunbeam, and to examine it in a state of separation, as far as our eyes will serve us; for, in consequence of the different intensity of directive force possessed by the different parts of a ray of common light, some of them, in traversing the refracting lamina of a transparent substance, suffer a greater deflection towards the perpendicular than others; and hence they may at once be separated by transmission. Thus, suppose a ray R (Fig. 30), to be incident obliquely upon the medium A B, immediately on encountering the refractive force its parts are dispersed. The central, and that whose directive force is the strongest, passes most directly through. The others, according to their distance from this, are bent more and more towards the perpendicular. If, however, the second surface be parallel to the first, all the tints emerge parallel to the former direction, and, consequently, to each other. The rays, therefore, resume their position of symmetry, and the light remains white, as previous to transmission. But by destroying the parallelism of the two refracting surfaces, the dispersion will be greatly increased; and in proportion as each part was deflected towards the perpendicular, at the first surface of the medium, having to encounter the same power at the second, reversed, and acting in an opposite direction, it will be still farther deflected from its course of incidence. In this way, by transmitting a common pencil of perfect or singled light through a prism or cylinder of any dense substance, at right angles to the axis, without passing through it, the whole is resolved into its constituent parts. Consequently the luminiferous excitement is conducted without change of character through the radiant matter on the other side, and a white body, which intercepts the rays, is painted in as many colours as the eye can distinguish. That which is least refracted, is of course most contiguous to the angle of the prism employed in producing the spectrum, and that most highly refracted forms the other extremity.

Viewing luminous and illuminated objects in this way, through prisms applied to the eye, we find that none of them is illuminated by homogeneous light; and that all the colours of natural bodies recognized by the eye, however simple and uncompounded they seem, are really resultant tints. The most perfect display of colours which can be obtained, is by resolving a pencil of solar light into its parts by a prism, and receiving the dispersed ray on a white surface. Different results are indeed obtained, according to the nature of the substance used for dispersion. Some give pictures of the sun, for instance, two or three times as much lengthened by dispersion as others; but glass, though not very eminent for its dispersive powers, is commonly used as in other experiments. It is a substance, indeed, of very variable quality, and it is quite rare to find any considerable mass which is of uniform density and structure throughout; but its great limpidity, its considerable refractive power, its freedom from a polarized state when carefully annealed, and its admitting so well of being ground and polished in any form, render glass invaluable in optics.

When a solar ray, then, is dispersed by a glass prism, with the angle of its refracting surface parallel to the horizon, we ought to have, upon a white screen placed to receive it, an image of the sun, constituted lowest down of light from the central part of the incident ray, which we know already to be destitute of chromatic excitement, and therefore incapable of being detected by its colour. It has, however, been detected in a satisfactory manner by the thermometer. Then follows a series of colours, from red to violet, which are insulated or blended more or less completely, according to the magnitude of the incident pencil. It seems impossible, however, by this experiment, to ascertain how many colours actually enter into the constitution of a ray of white light. Newton, to whom science owes these discoveries, believed that there were seven colour-making rays in one of the sun's light. Other philosophers have fixed upon five, four, and three; they seem to be infinite, and they all pass into each other.

There are five colours, however, which perform more important parts in nature than others, and it is easy to satisfy one's self that there are no others in the spectrum. These are Red, Yellow, Green, Blue and Violet. The spaces which they occupy respectively, depend upon the nature of the dispersing prism; but the more complete the dispersion, the more are the dark colours dilated. There is little reason to believe that the solar spectrum consists of individual parts, as a ray of solar light does; it is very probable that the different rays immediately upon emergence react upon each other, in the attempt to resume a condition of symmetry. The spectrum is more probably an exhibition of discord than of harmony; but it is well worthy of the consideration of philosophers, whether atoms of radiant matter, or of other bodies, when acting upon each other, do not observe certain intervals analogous to those of vibrating chords. That such was the case, Newton, who had perhaps a more comprehensive and clear view of the economy of nature than any other man, believed so firmly, that, having found the breadths of the colours, in the spectrum which he measured, to correspond, (and where the confines of the colours are so indefinite, the correspondence is not wonderful), with the intervals of the minor diatonic scale in music, he rested satisfied, without suspecting that different spectra assigned different breadths to the same colours.

It might be expected that such destruction of the symmetry of a pencil of white light, as is implied in developing a solar spectrum, should be accompanied with great interference, and, consequently, the production of many dark lines among the colours. The naturally penetrating portions of the incident ray, however, viz.—Those which have the edges of the molecules vertical, supposing the axis of the prism horizontal, will not be subject to interfere. For if they are once constituted on the chromatic side of the prism, those which are similarly excited, and capable of interfering when the difference of the length of their paths is half an interval, cannot bend in the planes of refraction in which chiefly the symmetry has been destroyed, so as to meet in a point in which one molecule is common to two rays. They rather diverge and arrive at the white skreen without interference, expanding and illuminating the spectrum. But those whose edges are horizontal, or parallel to the axis, or refracting edge of the prism, will be very subject to interference, being easily flexible in the direction in which the refraction is made, and being in such a state of unsymmetrical relationship, that efforts will be constantly made to change the condition then existing. Now, in Fraunhofer's spectrum, that most acute observer has drawn nearly 600 dark bands across the spectrum, which he saw with his telescope; and those who have not seen them do not doubt of their existence. They are by far most numerous towards the dark end of the spectrum, partly because of the weakness of the directive force of the ethereal rays there, and partly on account of the denseness of the lumeniferous parts of the medium. Their existence seems to be explained by the views which have now been advanced; and the truth of these views might be tested by forming a spectrum of white light, singled by transmission through a pile of glass plates, or by the extraordinary ray of rhomboid having its principal section at right angles to the refracting edge of the prism. In this case, all the edges of the lumeniferous molecules would be parallel to the axis of the spectrum, and if the transverse bands appeared as before, their cause is yet undiscovered. The colours which are thus pictured by a dispersed ray of the sun's light, received on a white screen, possess very different illuminating powers to our eyes, those between the orange and green being by far the most efficient. From this, which is generally much nearer the red than the violet end of the spectrum, the illuminating power gradually abates, as indicated by Fraunhofer.

It is not to be wondered, then, that the spectrum should produce the same phenomena as a peculiar sort of voltaic combination, even though we were to suppose that the external and central parts of a ray of solar light were in the same galvanic state. The dissimilarity of their state of excitement, however, as has been already shewn, will produce the result, that the constituent hollow prisms surrounding the central one act upon each other as if they were dissimilar substances, and that the central portion or axis must be positive, and the circumference negative; and these states will, no doubt, be continued after transmission. That the chemical agency of the spectrum, under any hypothesis, should extend beyond the region visible to our eyes, is nothing wonderful. Perhaps experiments might be devised with nocturnal animals, which would lead us to discover to what region of the radiant medium, excited by the transmission of a solar ray, their spectrum belongs.

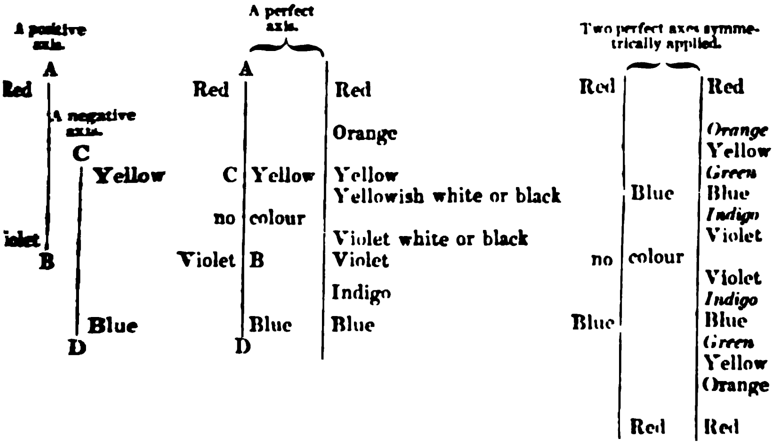
The resolution of white light into its constituent tints, by transmission, is the cause of many of the most beautiful colours in nature, though, probably, it will be found that the doctrine of unequal refraction has been extended to explain phenomena arising from other causes. As we descend in the ocean, the colour of the water successively changes from green to yellow, and ultimately to red; the lumeniferous excitement of the different rays of the sunbeam being successively quenched during the transmission, according to their weakness of directive energy. The same happens in the atmosphere. In a fog, the lamps in a city burn with a red light, and when the sunbeams are transmitted through dense air, as at sunset, the clouds lying in the line of the transmitted rays often exhibit the same tints, of most ethereal brightness.

But the partial destruction of white light by transmission, seems inadequate to explain the colours of most solid bodies, which, in their development, indicate the laws of polarized subtile matter so perfectly, as to leave no doubt that they arise from the formation of chromatic axes, whose consecutive poles are recognised as complementary colours. It becomes valuable to possess a character by which the polarized tints may be distinguished from those which seem to arise more mechanically from the refraction of white light, incident at the surface, which appears coloured. Now, this test we possess in the fact that bodies which are coloured by their chromatic polarity, must transverse the ray where they intercept it, so that on opposite poles of the chromatic axis, it must be singled in opposite planes like the pencils of a doubly refracting crystal; for it has been already shewn, in reference to the structure of a molecule of light, that transverse edges imply consecutive polarities. The same principle extends very broadly over the whole aspect of nature, and relieves the study of chromatics of a hypothesis, the conception and development of which has demanded too high an achievement of genius to be true. If this transversing could be explained as a mechanical twisting of the pencil during its transmission through the plate which exhibits the consecutive colours, it would not be necessary to innovate upon the doctrine, which regards the transmitted tints simply as a continuation of the incident pencil, deprived of certain colours that are detained on the side of incidence. This conception approves itself to the mind by its simplicity, and it seems also not unsuitable to the radiant mechanism which has been presumed in this work. But were this the cause of complementary colours, the transmitted rays ought to be singled at right angles to the reflected rays, whereas they are found to be singled parallel to the reflected rays, that is, at right angles to the penetrating part of the incident ray. This circumstance marks a very important distinction between two classes of colours. One is a more mechanical phenomenon, in which gross bodies are coloured, simply because they intercede rays of light, which are dispersed and deprived of certain tints necessary to whiteness at their surfaces. The other is a true colour on a gross body itself, arising from the state of free polarity in which its own light exists, and requiring only a pencil of white light to announce it. In this white light the colour acts upon the rays of its own kind, according to the laws of subtile matter,—repels them towards the eye, and renders the surface visible in its true tint. If the pencil incident upon it do not contain tints of its own kind, it remains dark, or its colours are somewhat changed by induction, so that it becomes capable of being somewhat illuminated by the incident pencil, appearing homogeneous with it. This induction generally lasts only during the time when it is under the unnatural exposure. But some bodies which are much under the influence of extrinsic light, such as the chloride of silver, seem to sustain the colour which has been induced upon them, till it is changed by another induction, or some agency affecting the electrical state of the substance, and altering the character of its chromatic axis.

I suppose, then, that when a ray of common light, in its most natural or symmetrical state, arrives at an opaque body, it is met by that body's superficial light in a state of free polarity, with a force depending on the constitution of the body, and those rays of the common light incident upon it are repelled or reflected, which are of the same tint, and thus indicate the colour of the body to the eye. The other tints of the common light being dissimilar, are not repelled, and, arriving close upon the opaque body, transfer their excitement to it, so as to excite it to a greater or less depth.

If we could see the whole of a *perfect* chromatic axis, insulated, so as not to induce colour on contiguous bodies, the principal tints which it would display on both hands of the central, neutral, or achromatic region, would be yellow and red towards the positive pole, violet and blue towards the negative, the central region being destitute of colour. Suppose now such an axis to be divided in the middle, and thereby resolved into two subordinate axes; the yellow must now become the consecutive pole to the red, changing to green or blue, while a neutral region is opened up between them. In the other subordinate axis, consisting of violet and blue, the violet must obviously become the consecutive pole to the blue, passing through crimson to red, and leaving a neutral interval. Thus these two subordinate axes, supposing them still contiguous, are arranged with consecutive poles opposite, as it ought to be. By the phenomena of the subdivision of a perfect chromatic axis, then, we see the relation of yellow to blue, and of violet to red. Such an axis may in a manner be regarded as compounded of two of equal length, one positive, the other negative, both overlapping each other, so that they may not destroy each other's polarity,—that is, one pole of the negative axis occupying the neutral region of the positive axis, and one pole of the positive axis occupying the neutral region of the negative axis. The negative axis includes the blue and yellow colours, the latter being the positive pole; the positive axis includes the red and violet, the former being the positive pole.

A perfect axis, besides these, contains compound tints, such as orange and indigo; the former of which is the resultant tint of the two positive poles, red and yellow, the latter of the two negative poles, violet and blue.


A positive axis.
A
Red
A negative axis.
C
Yellow
iolet
B
Blue
D
A perfect axis.
A
Red
C Yellow
no colour
Violet B
Blue
D
Red
Orange
Yellow
Yellowish white or black
Violet white or black
Violet
Indigo
Blue
Two perfect axes symmetrically applied.
Red
Blue
no colour
Blue
Red
Red
Orange
Yellow
Green
Blue
Indigo
Violet
Violet
Indigo
Blue
Green
Yellow
Orange
Red

Thus, let AB be a chromatic axis, whose light is not free to display all the tints, in consequence of the electro-positive state of the forms in which it is evolved; one aspect is red, the other violet, and probably the intermediate region, instead of being neutral, is crimson. Let C D be an axis under electro-negative influence, from similar circumstances yellow is on one aspect, blue on the other, and probably the mass is green. Let now the electric state of both be brought to quiescence by overlapping, but the colour preserved by the resultant axis being expanded, as in A C B D; we have now a perfect chromatic axis displaying red, yellow, and a resultant orange, on one side; then a neutral plane, then violet, and blue, with a resultant indigo, on the other side. If, then, a positive and negative axis be applied to each other, so that the pole of the one is applied to the neutral region of the other, as described, the chromatic arrangement becomes perfect, and the axis, if made to revolve very rapidly round its neutral part, would produce the sensation of whiteness; but two perfect axes, symmetrically overlapped, and in positions conformable to the laws of polarized action, if made to rotate, would produce a coloured fringe, consisting of concentric circles, the innermost of which is violet, the next indigo, then blue, then green, then yellow, then orange, then red; the indigo, green, and orange being resultant or induced tints. The extreme red would also induce a tendency to violet contiguous to it, for this is the negative pole of the red axis; hence, when a red pole is strong, it will be apt to produce a scarlet; and the blue pole consecutive to it, and which forms its true negative pole, must sympathise in its tint. A strong blue pole again, where it has a neutral space around it, will be apt to induce upon that region the consecutive pole of the blue axis, that is, yellow, and to produce the sensation of green, with which the consecutive red must sympathise. Thus, in a region where a strong red pole predominates, the tints will be scarlet, and its corresponding blue; where the blue pole predominates, they will be green, and its corresponding red. Where, then, there is a series of chromatic axes that are more or less confluent, and mutually act on each other; if red predominate at one pole, as towards the centre of the fringe, blue must predominate towards the other pole, or towards the circumference. In these circumstances the central fringes, instead of red, must seem scarlet and blue; and those towards the circumference must seem green, and a dull red. On intervals contiguous to the scarlet and positive region also there must be yellow; on intervals contiguous to the green and negative region, there must be an indigo tint. To illustrate these views in detail would require much space. But as they have been stated, they will be easily compared with the principles of polarized action already stated, and they will be found, by those who take the pains, to aid in the explanation of the coloured fringes of object-glasses and crystalline plates.

The chromatic axis, like those of electricity and magnetism, is compatible only with a certain length, which varies in different substances. After this, a repetition of poles occurs. If, however, there be no coercive force to sustain the insulation of the successive poles, the contiguous complementary colours will constantly unite, and a ray of light will pass along the axis, without suffering any change, as the magnetic or electric polarity is transmitted along a bar of iron, or other conducting substance. Yet, still even the most perfect and passive conduction implies a continuous series of chromatic axes, whose least length is the axis of a radiant atom. This, then, may perhaps be taken as the type of the mode in which conduction of subtile matter usually takes place.

We cannot acquire any knowledge respecting the constitution of the chromatic axis, by examining opaque bodies, for only one pole is exposed, viz., that on which the light is incident; and if we attenuate them to the degree to which they transmit light, the quiescence of their natural structure, or the natural condition of their surface, is destroyed.

This object may be obtained, however, by extending transparent liquid bodies in exceedingly thin laminæ, or by smartly tearing off a film of mica adhering to wax. If, in this way, we obtain a film whose thickness is probably between five and fifteenth millionths of an inch, it will be splendidly coloured with some tint corresponding to its thickness, and on its opposite aspects the consecutive tints or poles will be found, as in other cases. But as the radiant medium itself may be formed into chromatic axes, and we are better acquainted with its structure than that of any other body, we may first examine the phenomena of colour presented by it. When we inspect minerals that have met with accidents, we often find, when viewing them in different aspects, that they are traversed with irisated plates, evidently arising from fissures that traverse them. It often happens that a fissure displays all the phenomena which have been noticed at once, and thus enables us to detect the circumstances which produce them. Thus, a fissure is often propagated from some face of a mass of carbonate, or sulphate of lime, or quartz, varying in the width of its opening from that which is wide enough for the transmission of air, to that which differs but a very little from crystalline contiguity. Such a cavity as this, to a great depth, after it ceases to admit common air, must continue to contain radiant matter, the solid matter of an atom of which is much less than that of an atom of vital air, or of nitrogen; and wherever there is a cavity of sufficient magnitude for accommodating the radiant matter, into it this vapour of matter will ascend from the walls which contain the vacuum, and there it will give rise to its specific radiant action. It does not follow that there is free radiant matter, however, in every cavity from which colour is emitted, or through which light may be transmitted. For the walls of this cavity being themselves nothing else than concrete radiant matter, may become coloured, or transmit light, if their mutual distance be not too great.

When we inspect a prismatic or semilenticular cavity in a mineral, such as that which has been described, we observe, most contiguous to the solid part, a band reflecting white light, passing into a bluish tint, where it vanishes in the solid mineral; beyond this broad silvery band there is one of brownish yellow, and another of brownish purple.

If the fissure be very small, this series is merely represented as a silvery band, succeeded by a black or purplish black one. After this, there is a bright blue band, a dingy silvery band, and a yellow one, succeeded by crimson. Then another series of blue, greenish yellow, and red; a fourth of green and red; a fifth of bluish green and red; and so on. These bands are broader in proportion as the region in which they are found is thinner, and of all, the brightest is the second, which, on a general view, presents two colours, scarlet and blue. In this and the successive fringes, these tints sympathise with each other; so that when the scarlet becomes dull and red, the blue becomes dull and greenish, and is evanescent in the outer rays before the other. When viewed by transmitted light, tints complementary to these are seen in the same spaces; but, from the imperfection of their polarity, they are generally much less bright.

These coloured rings having been accidentally noticed by Newton, when applying the faces of two prisms to each other, attracted his attention; and he investigated the phenomena so accurately and minutely, that little has been added to the inquiry regarding their physical constitution, from his day to that of M. Arago, to whom every branch of science, and especially physical optics, is most deeply indebted. In reference to these coloured bands, this philosopher has brought to light some very important circumstances. Newton formed the rings at pleasure between a plane and a convex object glass of a very long focus; and M. Arago pursued the same method in his very interesting inquiries. To him we are indebted for the observations that enable us to regard these rings as true colours, in the production of which the radiant matter acts the part of an opaque or coloured body, or induces this state upon the dense matter immediately contiguous. If the colours on opposite aspects were occasioned by a reflection of part of the incident light, and a transmission of the remainder, the interval between the glasses merely acting as a filter, according to the Newtonian hypothesis, the reflected and transmitted rays ought, if singled at all, to have the edges of their molecules in opposite planes. But M. Arago found, that, when the rings were viewed by transmitted light, the ray at the eye possessed the same characters as if it had been incident on that side, and reflected in the same direction. The ethereal ray, then, interrupted at the region of colour, has its poles or edges transversed at that region, which is the action of a true chromatic axis. It has also been shewn by the same philosopher, that a pencil of white light, singled in a particular way, may be transmitted through the interval between the glasses, without the development of colours; and that the Newtonian hypothesis is inadequate to account for the production of these coloured rays *. It has likewise been shewn, that air is not necessary to their developement; indeed, it is extremely probable that the interference of air is a principal cause of their evanescence. Sir William Herschell has also proved, that a transparent medium, through which, we may view the coloured rings, is all that is requisite, and that they are produced when a lens is laid on a metallic plate. They must, therefore, be formed at the glass by the aid of radiant matter alone.

The only series of radiant atoms which can transverse the ray on opposite sides, are axes (Fig. 24), consisting of 1, 3, 5 7, 9, 11, atoms, and so on, in the progression of the odd numbers. In the even numbers, the extreme edges are parallel, and well suited for a simple transmission. The first member of the latter series is one molecule; the second, two; the third, three; the number of atoms being 2, 4, 6, 8, and so on, in the series of the even numbers. The first series, then, will be ordinates to the tangent or verse sines, in the progression 1, 3, 5, 7, 9, 11; and, consequently, if they determine the coloured rings, the squares of the sines, or of the diameters of the rings, in these very small arcs, ought to be in the same progression; and this is found by experiment. These deductions as to numbers have already been made by Newton; and they express the general laws of colour rings developed by symmetrical structures; for the same relationship of the circular areas to the length of the successive axes would fol-

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* Mémoires Arcueil, vol. iii. p. 246.

low, independently of this mechanism, from the universal law of subtile matter, which is, that its intensity, corresponding to given distances or intervals on the axis, shall be represented by *areas* at right angles to the axis, which are expressed by the same numbers. Every coloured ring ought also to have its complementary on the opposite aspect, and the intensity of both ought also to be equal, provided the light be incident only on one side; for two poles of one axis always tend to be equal. But, if light of equal intensity be incident on both sides, then colour cannot be developed; the polarity of the axis is destroyed, in the same way as when we expose a bit of steel at both its extremities to the similar poles of two magnets. These conditions are found to hold in experiment. The last, M. Arago has suggested as a means of comparing the intensity of two lights; and we see that it would be a photometer very independent of heat, and analogous to an electrometer.

When any small cavity, then, is generated in a pellucid mineral, as by a fissure, it must be speedily filled with radiant matter, wherever there is room for its atoms. The radiant matter occupying the cavity will, for a certain breadth, exist as a lamina one atom thick. This will form a chromatic axis, and a fringe of colour will be displayed by it. Then there is an interval of two atoms through which light may be more easily transmitted, but which, in favourable circumstances, will be coloured by induction. Then are three atoms which constitute another chromatic axis, and so on; the areas or squares of the diameter of the fringes, when the cavity is formed by two spherical domes of very large radius, being always proportional to the numbers 1, 3, 5, 7, 9, 11, &c.

This opacity and colour, which is communicated by thin plates of radiant matter to the transparent walls which confine them, is also induced on all transparent bodies when they are reduced to laminæ of great thinness; and, perhaps, this method might be of great value, in enabling us to discover the colours of the particles of bodies, which, in the crystalline state, are only white or limpid. Thus, when the wind breaks the little waves of the sea, and throws on shore the salt water as foam, and then urges the best formed bubbles up the beach; by-and-by, they lose much of their water, become very highly saline, and beautifully coloured; nor when they are in their best state, do they present any colours more frequently, nor do any continue so permanently as bronze and violet; so that they seem as if they were little capsules filled with chlorine or iodine. On inspecting them minutely, these colours are found to arise from streaks that are quite opaque, and of which the greenish yellow, in particular, possesses a metallic lustre. The very frequent recurrence of violet, and its various purple and blue tints, in sea salt and its flame, in iodine, in many of the crustacea, and radiata, particularly the medusidæ, and in many algæ—and of bronze and other tints, which are complementary to the former series, in chlorine, and a great many thalassyophytes, leads us to suspect that these are the colours of the marine particles. In like manner, by dissolving bodies in water, and forming the solution into bubbles, perhaps we might detect the colours of the particles of the bodies dissolved, which transmit light too easily in the crystalline state for the developement of visible chromatic axes.

But not only do fluid bodies become opaque and coloured, when reduced to an extreme thinness; all transparent bodies do so, and they display a colour depending on their thickness. Beneath a certain degree of tenuity, they are incapable of reflecting light, and are either black or invisible, according to the position in which they are held in reference to the eye. When their thickness becomes a little more considerable, they become beautifully coloured with various tints, depending on their actual thickness, complementary colours being always found on opposite aspects. When the thickness is increased a little more, they again become transparent. Insulated laminæ, of such thinness as to be coloured on that account, are not of frequent occurrence, but flies' wings seem often to be iridescent and opaque from this circumstance. It would be very interesting if we could discover the number of radiant atoms in solid bodies, entering into their particles in such positions as to produce chromatic axes from violet to red. In fact, we should, by this knowledge, become possessed of an instrument of analysis far more exquisite than any which we have at present. The resolution of bodies into smaller particles of dissimilar electrical states by Voltaic energy, and some other methods of analysis, has indeed given us much insight into the composition of many natural bodies; but many of the most curious phenomena, and such as seem most essential to the constitution of the substance considered, are often too delicate to acknowledge the rude applications of the laboratory, which is an inquisition where confession is never made without torture. If we understood the mechanism of colour, how specific would be the information which we should obtain in reference to the constitution of venous and arterial blood; and many substances similarly related, which, though yielding the same products on destruction, are possessed of very different properties?

We may, until we know better, assume that laminæ, whose particles contain only one radiant atom, so placed as to give colour, are violet, when the light is most favourably incident upon them; that an axis of three atoms gives blue on the pole contiguous to the incident light; five, green; seven, yellow; nine, red; eleven, violet again, of the second order; and so on. Perhaps this view would enable us to understand the origin of those colour-suits which are observed in the same organization, and which at first sight seem to have no relation to each other. Thus, in the petals of flowers, which we should expect to possess the same structure in their different parts, we often observe a violet and yellow, a blue and red. That transition of colours observed in the solar spectrum, is extremely rare in the colours of natural bodies. Let the accompanying Table represent the series of axes to the ninth spectrum. It will be seen from it, that a body, possessing only one chromatic axis, as it possesses one specific character in other matters, will nevertheless give different colours, according to the contiguity of its parts.

			Suit of Blue.		Suit of Yellow.		Suit of Green.	Suit of Violet.		Suit of Red.	
1.	Violet,	1	- -	Purple	-		-	-		-	
	Blue,	3	Blue		-		-	-		-	
	Green,	5	- -		-		Green	-		-	
	Yellow,	7	- -		Yellow		-	-		-	
	Red,	9	3 × 3 Red		-		-	-		Red	
2	Violet,	11	- -	Wh. Blue	-		-	Violet		-	Orange
	Blue,	13	- -		-		-	-		-	
	Green,	15	3 × 5 Gr.		-		5 × 3 G.	-		-	
	Yellow,	17	- -		-		-	-		-	
	Red,	19	- -		-		-	-		-	
3.	Violet,	21	3 × 7 Viol.	Wh. Gr.	7 × 3 Viol.	Blue	-	-		-	
	Blue,	23	- -		-		-	-		-	
	Green,	25	- -		-		5 × 5 G.	-		-	
	Yellow,	27	3 × 9 Yell.		-		-	-		9 × 3 Y.	
	Red,	29	- -		-		-	-		-	
4.	Violet,	31	- -	Purp.	-		-	-	Bluish	-	Yell. Green
	Blue,	33	3 × 11 Blue		-		-	41 × 3 B.		-	
	Green,	35	- -		7 × 5 Gr.		5 × 7 G.	-		-	
	Yellow,	37	- - -		-		-	-		-	
	Red,	39	3 × 13 Red		-		-	-		-	
5.	Violet,	41	- -	Wh. Blue	-	White	-	-	Green	-	
	Blue,	43	- -		-		-	-		-	
	Green,	45	3 × 15 Gr.		-		5 × 9 G.	-		9 × 5 G.	
	Yellow,	47	- -		-		-	-		-	
	Red,	49	- -		7 × 7 Red		-	-		-	
6.	Violet,	51	3 × 17 Vi.	Wh. Gr.	-	Purple	-	-		-	Gr. Blue
	Blue,	53	- -		-		-	-		-	
	Green,	55	- -		-		5 × 11 G.	11 × 5 G.		-	
	Yellow,	57	3 × 19 Yl.		-		-	-		-	
	Red,	59	- -		-		-	-		-	
7.	Violet,	61	- -		-	Gr.	-	-	Greenish	-	
	Blue,	63	3 × 21 Blue		7 × 9 Blue		-	-		9 × 7 B.	
	Green,	65	- -		-		5 × 13 G.	-		-	
	Yellow,	67	- -		-		-	-		-	
	Red,	69	- -		-		-	-		-	
8.	Violet,	71	- -		-		-	-	Yell.	-	
	Blue,	73	- -		-		-	-		-	
	Green,	75	- -		-		5 × 15 G.	-		-	
	Yellow,	77	- -		7 × 11 Yel		-	7 × 11 Y.		-	
	Red,	79	3 × 23 Red		-		-	-		-	

Suppose that the specific chromatic axis of an organic body, such as a petal, is blue, originating from three atoms of radiant matter chromatically disposed in reference to each other, then, if all its axes be insulated, the whole will be blue. If its laminæ be arranged in pairs, or two chromatic axes be continuous, it will be transparent, for six radiant atoms do not constitute a chromatic axis at all, and so of all the even numbers. If three axes be continuous, the body will be red, being the same as if it possessed one chromatic axis of nine, which gives red on the aspect of incidence. If five axes are continuous, it will give green, and this is its only colour of the second spectrum. In the third spectrum, specific axes of three atoms by union, will give violet and yellow; in the fourth, they will give blue and red, as in the first, and the suits are repeated. If the specific chromatic axis of a body is 5, or green, it can only give green in all the spectra. The suit of 7, or yellow, is violet next to yellow, then green, red and blue, after which the yellow returns. The red gives its suit in the order of the colours of the prismatic iris, but only in the alternate spectra; and the violet gives the suit of the prismatic iris, taken the other way. Such are the true colours of the poles, but those which arrive at the sensorium will often be resultant tints; so that every axis has two colour suits, and this immediately adds white and purple, and many other resultant tints.

If, then, there be a chromatic apparatus, as for instance a fibre, or surface containing fibres, composed of radiant atoms odd in number when it is illuminated by light most obliquely incident, supposing that the most superficial atom only is excited, the visible pole will be violet, which, in consequence of the extreme opacity of the body, will be very strong. If the light be less obliquely incident, and illuminate three atoms, it will be blue, and more vertically it will be green, or even yellow. If it be violet, at a vertical incidence, it can only become black by viewing it obliquely, unless the violet arise from a depth of eleven being illuminated, and not from one. This we may often infer to be the case, and it explains the intimate connexion of violet and red colours, though, in consequence of the difference of the radiant movements which indicate them, they are separated in refraction by the whole length of the spectrum. If, then, a body possess a chromatic axis so perfect that it gives violet of the second order at a nearly vertical incidence, by successively increasing the obliquity we shall obtain purple, red, orange, yellow, green, blue, and, perhaps, violet again, a series the reverse of that which was formerly obtained; but in this case, perhaps the violet given by light nearly vertical, would not have a high or metallic lustre in consequence of its depth, which is eleven atoms. Such is, perhaps, the mechanism of the development of the colours of natural bodies, which, though on a different hypothesis, gives results similar to those of Newton. But by means of crystalline structures, and singled light, philosophers are able to impart opacity, and the most splendid tints, to plates of matter, which are naturally quite transparent and colourless.

Let us look through a rhomboid of calcareous spar, at a singling reflector, such as glass, or a varnished surface, holding the rhomboid so that its principal section (or the plane in which the two images of any object viewed are always found, where common light is used) coincides with the plane of reflection, that is, so that the edges of the radiant molecules of the singled pencil come on transversely to the axis of the rhomboid. As soon as we have hit upon the singled pencil, rising up from the reflecting surface, a bit of glass interposed between the reflector and rhomboid will be seen single, as if it were viewed by the naked eye; and this will also happen if we use a drop of liquid, or any body which is solely illuminated by the singled light, and which does not, from some peculiarity in its intimate structure, change the character of the light incident upon it. If now we gradually move the rhomboid from its present position (in which the radiant edges are incident perpendicularly to the plane of its principal section), to a transverse position, we shall find that, soon after destroying the symmetrical relationship of the crystalline axis and the radiant edges, two images of the glass appear, one of which is brighter than the other, till half a right angle has been moved through, when they are equally intense. As we move round the rhomboid towards a position transverse to the first (in which only one bit of glass was seen), one of the two images during the motion through the quadrant becomes gradually dim again, till, in the transverse position of the rhomboid, it has vanished altogether, and a simple bit of glass only appears, as when the principal section of the rhomboid was in a position parallel to the plane of primitive polarization or reflection. The same phenomena take place, when the rhomboid is moved through the other three quadrants. Now, from what was said of the changes produced on a singled pencil, when transmitted through a rhomboid of calcareous spar, it follows, that, when a thin plate, as for instance a lamina of sulphate of lime, between $\frac{1}{20}$th and $\frac{1}{60}$th of an inch thick, is placed in a beam of singled light, with its principal section, or neutral sections, forming angles between 0° and 90° with the incident edges of the singled light, each incident ray will be resolved into two, distant on the emergent side of the plate by a very small interval. These rays, then, constituted in the thin plate of sulphate of lime, may be compared to one of those galvanic probangs, consisting of a filament of gold and silver, united at one extremity, and a little open at the other, which physiologists use to distinguish nerves from vessels of circulation. We have both poles of a chromatic axis on the same side of the plate, and so near each other as to act directly across the atoms which lie between them. The distance between the poles, then, will correspond to the thickness of the thin plate of any substance which will give the same tints. In different laminæ of the same mineral, the colour will vary in the same ratio as the thickness, so that having ascertained to what part of the Newtonian table of colour for thin plates of radiant matter, the colour developed in the crystalline plate by any given thickness belongs, we may determine the colour afforded by any other thickness, provided no change takes place in the polarizing intensity of the crystalline plate, as the thickness increases.

There are a great many chances that the tints thus developed should be scarlet, or blue, red, or green. If the interval between the two chromatic poles on the emergent side of the thin crystalline plate correspond to an axis of only one radiant atom, the tints will be a faint violet, and yellow; if to 3, blue and scarlet; if to 7, a good yellow and violet; if to 9, a red and blue. Independently of numerical superiority, we shall afterwards find, that, in the atomic constitution of bodies, the numbers 3 and 5, and their multiples, are of constant occurrence, while 7 and 11, which yield violet and yellow, are of exceedingly rare occurrence. It may often happen, however, that in these plates, as there are great elevations and depressions on a crystalline surface, a variety of chromatic axes may be developed, in which case we shall have resultant and composite tints not truly found in the photochromatic scale.

But since the tints are constituted simultaneously on the same side of the plate, at distances far too minute for the eye to discriminate, and are always of equal intensity, and complementary to each other, their resultant in the eye is a colourless transparency, and the actual colours cannot be projected on a screen any more than on the retina. It comes, then, to be an interesting inquiry, how we are to ascertain their existence?

From what we have already learned of the power of a rhomboid of calcareous spar to permit two rays of light, of opposite polarities, to pass through its principal section, without blending them, or otherwise affecting them, but by removing them to a greater distance from each other, we are prepared to find that such a rhomboid is the very apparatus which we wish for, to separate or analyse the two sets of consecutive rays, propagated simultaneously, and almost coincident, between the eye and the thin plate. When the rhomboid is applied (the crystalline lamina being continued in singled light), each of the two images which it gives of this lamina, must be constituted by one of the two sorts of rays only; and, of the images must have the colour of one of the chromatic poles developed on the near side of the crystalline plate; and the other image must have the colour of the consecutive pole. Should the images, in consequence of the largeness or nearness of the crystalline lamina, or the want of depth in the rhomboid, partly overlap each other, the common or overlapped portion will be colourless or neutral, like the plate itself, viewed with the naked eye. If the analysing rhomboid be moved through 90°, so as to place its principal section transverse to its former position, there must be a complete exchange of colour in the two images, accompanied with a corresponding change in visible direction; and it is to be remarked of the two images, accordingly, that, after such a movement, they have exchanged colours—that which was at first scarlet, red, or yellow, being now blue, green, or violet.

In intermediate positions of the rhomboid, each of the two incident pencils must be decomposed into two; and at the middle point, in the revolution through the quadrant, the colours must vanish; for the two rays are then equal to each other, and the reception of both into the eye must produce a sensation of limpidity only. By moving the rhomboid, then, the polarized or singled light is dechromatized more or less, and at 45° is neutral and colourless, like common light. In causing the rhomboid to rotate through the whole circumference, at 0° and 180°, it will give the two colours of the plate; at 90° and 360° it will give the same colours, but assigned to different images; and at the intermediate azimuths of 45°, 135°, 225°, and 315°, both images will be colourless. Any other doubly refracting solid will shew the complementary colours of the plate, simultaneously, as well as a rhomboid of carbonate of lime; and one constructed by Mr Rochon, out of two pyramids of quartz, is much more convenient. To exhibit the two tints successively, neither one nor other is required, nor any apparatus more complicated than a plate of glass, inclined at the singling angle to the two sets of rays propagated from the crystalline plate. In one position, it reflects one set and absorbs the other, thus announcing the colour of one pole only to the eye; while, in a position applied to the chromatiferous light at right angles to the former, either on the right or left, it completely absorbs the pencil which it reflected before, continuing to the eye the other pole, and announcing its colour. In the intermediate azimuths, it reflects a part of both sets, and, at the middle of the quadrants, both in equal quantities; from which neutrality or whiteness results, as when the plate is directly viewed by the naked eye. For common purposes, however, it is convenient to use a thin slip of coloured tourmaline, cut parallel to the axis of the prism in which it crystallizes. The axis will represent the direction of the edges whose light alone (if it be not too thin) it will transmit. We obtain, then, first one true colour, tinged by the colour of the tourmaline; then, by moving the analysing slip through a right angle, the changes described, till, at 90° distant from its former position, the consecutive pole appears in its strongest colours. Besides tourmaline, a plate of agate, cut across the laminæ, a pile of glass-plates, or films of mica, held so that the light is transmitted obliquely through them, may be used. But a perfectly colourless singling plate is still a desideratum in these beautiful experiments.

As one of the bifurcated portions continues to propagate light whose edges are singled in the same plane on both aspects of the lamina, the other may be regarded as the chromatic axis; that whose polarity is not changed, serving rather as a conductor, analogous to the armature of a magnet, for bringing both poles, which are on opposite surfaces of the lamina, into each other's vicinity, on the same side, so that the contiguous extremities may be coloured. In this case, the ray which preserves the primitive direction of edges, generally gives the negative the green, blue, or violet tint; while the other gives the positive, the red, crimson or yellow. If we suppose that the incident light is positive, compared with that of the crystalline lamina, and that it merely excites the chromatic axis, then the pole of the axis, or aspect of the lamina, most contiguous to the incident light, will be negative; and, from this point, the ray not transversed conducts that colour to the other side, or that next the eye, without changing its polarity. According to this view, the dark tints ought to be on the central aspects of fringes. Or, if we suppose that the incident pencil is negative, and that its own polarity is transmitted in a continuous stream to the surface of the crystalline lamina next the eye, where the two poles are contiguous, it will, in like manner, give a negative tint. In cases where chromatic axes are developed in nature, and seen in common light, one of the parts of the incident ray seems to illuminate or excite them, and the other to render them visible.

The colours of thin plates generally, then, are presented in two series. One is developed simply on account of the thinness of the plate, which becomes compatible with a single chromatic axis. This display is confined to the most attenuated laminæ, is visible in common light, and is analogous to the colour of most natural bodies. Supposing that the lamina is a fragment of a polarizing crystal, after it has attained too great a thickness for the institution of a single chromatic axis, it loses its opacity and colour, and simply transmits common light, not much affected by it. But when its thickness is too considerable for its becoming coloured in virtue of its thinness, it begins to repeat the same series of tints as it grows thicker, in consequence of its double refraction. Its thickness, which destroyed the first series, is the means of developing the second. The first series, then, may be represented by coloured laminæ, held at right angles to the optical axis, or with their disks fronting the eye; the second, by the same laminæ held in the plane of the optical axis, or with their edges fronting the eye. In the first series, we see only one pole at a time; in the second, by that apparatus which has been mentioned, we may see both as we should do were our eyes good enough, when the edge of a thin plate, coloured by its thinness, is turned towards the eye.

If $r\ r'$ (Fig 31.) be the thickness of a thin plate, which gives certain tints in natural light, the doubly refracting plate, A B, to give the same tints, must have a thickness equal to the product of the thin plate, and the cotangent of separation between the two rays, at a vertical incidence, possessed by the crystalline lamina. Or, calling the angle of bifurcation proper to the lamina λ, the thickness of the idiochomophanous plate t, and that of the doubly refracting plate, which gives the same tints in singled light, T: then $T = \frac{t}{\text{tang. } \lambda.}$ Thus it appears that the colours of crystalline plates do not depend absolutely on their thickness, as is the case with thin plates, but on this element, combined with their doubly refracting power; and hence a plate of a very weak doubly refractive intensity may become coloured, though its thickness be very great.

The weakest sort of polarizing action seems to be that of certain liquids, and even vapours, such as turpentine and syrup, inclosed in tubes; and, among mineral bodies, that which takes place along the axis of quartz. Not only is the incident ray not bifurcated, but it requires a considerable thickness to transverse it, which must, of course, be greater in proportion as the directive force of the incident tint is greater. The next degree appears to be that in which the plate simply transverses the incident pencil, as is the case when a rhomboid of calcareous spar is applied to a ray singled by reflection, with its principal section parallel to the incident edges; and the highest degree is that in which the incident pencil gives rise to two, which, when of equal intensity, are transverse, or complementary to each other.

Such are some of the most interesting phenomena presented by thin doubly refracting laminæ, in which the polarizing force is equal in intensity all over the plate, except in the neutral axes. But in plates possessing individuality of form, such as equatorial laminæ, taken from crystals which are not tessular, in planes at right angles to the axis, other phenomena become visible, which possess the most beautiful and interesting characters. In fact, in viewing such a lamina in singled light, we are viewing the base of the ray of light proper to the symmetrical medium examined; and a state of subtile matter, analogous to that which it has been presumed a ray of the radiant medium possesses, is exhibited before the eye in the most vivid tints, determined by the medium to which it is attached, but always retaining the same generic features. In the hope that the molecular structure of many bodies will soon be determined, this subject is now omitted, with the confident anticipation of the pleasure which any one will derive, who chooses to apply the principles of the structure of matter contended for in this work to all the phenomena of physical optics.

Analogous phenomena of still greater splendour may be developed by the partial distribution of heat in transparent structures, not naturally possessing free polarization or individuality of form. Thus, let a rectangular plate of annealed glass be examined in singled light, and it will exhibit no traces of polarization; but while it remains illuminated, and viewed with singled light, let one of its edges be applied to a hot body; "nearly at the same instant," the light of the surface contiguous to the hot body is thrown into a state of polarity; a perfect image of that state is speedily developed at the other edge or pole, and the middle, or equatorial region, contains the consecutive polarity. If a diamond cut be drawn through the equator, so as to divide the plate into two, though they be in their former position, there are now two polarized forms which are images of each other; and, by using pieces of glass of different forms, and crossing plates upon each other, the most strikingly beautiful figures are displayed, all of them perfectly illustrative of the habitudes of subtile matter, whose polarity is excited. If a model of a human brain were made of crystal, with ramifying tubes distributed internally for applying heat to it irregularly, should we not observe most interesting phenomena?

But, not only may glass, by an unequal distribution of heat in it, acquire an individual polarity or circulation, according to the form which it happens to possess; the radiant medium also, like any other transparent tessular medium, may be brought into the same condition, and the forms and tints which are developed are still more beautiful. Most admirable attempts have been made to explain them, solely on the principles of a mechanical interference of waves in an undulatory medium. What could baffle a genius like that of Fresnel? He always, when he errs, goes beyond rather than falls short of the truth. But, to dispense with half an interval at pleasure, is to dispense with all that ever can be required to make any phenomenon conform to the hypothesis of recurrent colours; and when, in addition to this, any one of many regions may be fixed upon as fit places for interference, it is not to be wondered if this doctrine has been extended to phenomena where it does not apply. The principle of the chromatic axis seems to me to act to a great extent in producing the brilliant spectra of a diffracted sunbeam. The phenomena will be alluded to at the end of the chapter on Radiant Heat.

OF VISION.

The apparatus by which the condition of external objects, as to illumination, is announced to the mind, is the Eye, an optical instrument of the most perfect kind, the aplanatic structure of the lens of which it has been the ambition of opticians to imitate, though hitherto with only partial success. Like tessular bodies, and such as want individuality of form, the eye acts upon light very passively, at least during life; merely conducting without change, like the radiant, which is contiguous to it, the lumeniferous excitement emanating from the objects before it. In consequence of its lenticular structure, however, the direction of the incident rays is changed, and, within the range of distinct vision, they are made to converge to a focus on the interior wall of the eye. There an image of external objects is formed; and, in an eye examined by cutting in upon the back of it, this image may be seen painted in its natural colours, as in a camera obscura. Whether the region where the image is formed possesses opacity enough, during the fluidity of life, to intercept and form a base to the rays meeting there, cannot be discovered. The wall, or cup, which receives the incident rays, is covered by a stratum of cerebral matter, named the Retina, which, in man, and most animals, reposes on a very opaque pigment. This pigment seems to perform a most important function in vision; and its colour is the index of that state of external lumeniferous excitement, which cannot produce vision. Being itself composed of radiant matter in a condensed state, this pigment must possess the light proper to the atoms of which it consists, in a certain state of excitement; and, when the state of the excitement of the external radiant matter is the same, no re-action can take place between them, it must be the same as to vision as if the eye were closed. The pigment of the human eye, when looked upon (other objects being excluded), excites the same sensation as the closing of the eye or the radiant medium at night. The optic nerve remains unchanged, and in the natural state of its illumination. Both night and the pigment are black. The state of their illumination is the same. If, instead of being black, it were white, that is, in an opposite state of illumination to what it is now, and to that of the radiant medium at night, the degree of radiant excitement fit for vision would undergo a corresponding change. In these circumstances, dark tinted, and obscure bodies, would be most distinctly visible; and the night would be the season best fitted for distinct vision. Now, it is remarked of diurnal animals generally, that they agree with man in having dark or nocturnal pigments; of nocturnal animals, it is remarked that the pigments of their eyes are light-coloured or diurnal. Each has a state of vital lumeniferous excitement, consecutive to that of the radiant medium, during the hours when its vision is most distinct. The lumeniferous excitement of the radiant medium during night, however, being much less considerable than during day, nocturnal animals have the whiteness of their pigments supplemented by large organs of vision, and often a lucid stratum on which the retina reposes. This lucid stratum, in that region in which it remains uncovered by the pigment, and is more particularly called the tapetum, displays a metallic lustre, which always indicates abundance of superficial light; and that its light is differently excited from that of the radiant medium by night, and that of our eyes, is shewn by this—that, in the darkest place, where every thing else is invisible, by the light of its lucid tapetum, a nocturnal eye, such as that of a cat, may be seen intently gazing at ours. The eyes of the animal only are in a dissimilar state of lumeniferous excitement from our eyes—hence we see only the animal's eyes; but the whole of our body and surrounding objects are in a state of excitement dissimilar to that of the nocturnal animal's eye, therefore, it sees all the surrounding objects, and not our eyes only. This state of lumeniferous excitement, of which the mucous pigment of the choroid coat is the index, must extend back to the sensorium of vision.

Are we to suppose that the whole matter of the optic nerve is the medium of the conduction of lumeniferous excitement, or rather, that its function is to secrete from its own matter, and to accommodate unembedded in its filaments rays of matter in the atomic state?

Such an idea seems to suit the phenomena of anatomy and physiology, and what we should expect as the crisis of organic assimilation. The whole series of chemical and natural bodies is thus made to lie between matter on both hands, in the ultimate or atomical state. But there is this remarkable difference between them,—that the parent atomic tissue is only one individual form, as vast as the universe; while the atomic tissues, to develope which is now assumed to be the ultimate function of compound matter, consists of many individuals, each having a specific form, and, consequently, a specific action, in every individual creature. Arguments for this mechanism will be advanced in the Fourth Book.

According to this view, a filamentary tissue of matter, in the same state as that of the medium of light, is the criterion of an animal nature. Its parts may be connected, and constitute one ramified form, in which case the animal possesses unity, and a greater or less sympathy of parts, according to the extent to which the whole sustains a common state; or it may be composed of unconnected parts, in which case the animal is imperfect, and has no common sensorium nor universal sympathy of parts. Cerebral matter thus holds a very peculiar place in the series of animal bodies changing spontaneously, during life, into the state of individual atoms, and thus having a power of the ultimate analysis of matter. In these respects, then, it may be viewed as the most perfect and potent mechanism in nature. But it is also reasonable to infer, that its matter is in such a state that the transition into free atoms is somewhat easily effected. Viewed in this regard, then, it is the most imperfectly organised part of all the animal, and is in the most rudimentary state.

After a review of all the phenomena, and experiments recently made by several physiologists, perhaps it will be readily received as very probable, that wherever there is a nervous filament capable of the reciprocal functions of forming the medium by which sensation and volition are propagated, a prismatic filament, or perfect ray of light, is developed within it; where the nerve is capable of executing only one of these functions, then a single ray; and when, by lesion or deficiency of secretion or assimilation, by the development of a ganglion, or otherwise, the continuity of this ray and the sensorium is destroyed, paralysis or insulation befals the ulterior region. A sufficiently perfect animal-mechanism remains for accomplishing the nutrition and assimilation of matter to that of the ulterior parts, but their continuity with the sensorium is interrupted.

As the simplest and most perfect mechanism, then, and that which might very naturally be expected to arise out of the circumstances of the case, we may believe, till more evidence be advanced, that, when a ray of light has arrived at the retina, or somewhere else in the back part of the eye, very probably at the confines of the hyaloid membrane, it is received upon the extremities of atomic rays, reposing in the optic nerves, and probably branching out into a coma, or pencil, which is at first interlaced with the retina, the points terminating among the sinuosities of the hyaloid. Along these rays, the specific lumeniferous excitement, conducted through the humours of the eye from the illuminated object, will be transmitted to the sensorium; and from the structure of the optic nerves in the region of the sphenoid bone, it follows that, at one part of their course, the rays from both eyes are very contiguous to each other. It seems impossible to devise a plan, by which the ultimate mechanism of the living eye can be discovered; in the mean time, therefore, we must rest satisfied with conjecture. It will not, in any degree, affect the general doctrines now advanced, as to the mode by which vision is effected, though we suppose that there are no such atomic rays insulated and symmetrically disposed in the optic nerve. On such a more rude supposition we have only to regard the whole as a fasciculus of imperfect rays, some parts of which only are fit for the transmission of lumeniferous excitement.

When the rays of light, then, emanating from any opaque body, enter the eye, they are made to converge, so that the whole image may be comprised in a very small area, where it has been supposed the extremities of the optic rays terminate; and that vision be distinct, it is necessary that this image be symmetrical as to the surface on which it is projected, and neither farther back nor farther forward than the region which has been mentioned. The lumeniferous excitement incident there, is now propagated without change,—that is, simply conducted as by the external radiant medium to the sensorium. While the illuminated object, then, continues to affect the eye by the incidence of its light, that object is seen in its true colours. Nor is there any more reason why it should be seen double, than why smelling a rose should awake the sensation of two, or hearing a musical instrument should lead us to suppose that two are sounding, and no reason at all why it should be seen inverted.

This view of the mechanism of vision leads us to infer that an image of a body painted in its complementary colours, may be expected as often as an illuminated state of the optic apparatus continues to exist, after the stream of lumeniferous excitement from the visible object has been interrupted. The atoms or ray between the retina and the sensorium then become polarized axes, of which the internal edges must retain a state of excitement consecutive to that on which, while the excitement continued to stream in, it was incident. When any pencil or spot on the retina has been very powerfully excited, it can also only be expected that it shall induce an opposite polarity on the surrounding region, so that the lucid image shall appear surrounded by complementary fringes. Farther, as the rays from two images formed either in the same eye, or one in each eye, come into each other's immediate vicinity in the region of the sphenoid bone, it follows, that two rays conducting lumeniferous excitement will be subject to react upon each other, and when the two rays are coloured by non-consecutive tints, they must sensibly alter each other, or give rise to an effort towards alternation. If, again, the two rays be insulated from each other, yet contiguous, and one of them conducts neutral light, while the other conducts coloured light, it may be expected, that, when they possess a certain degree of nearness, that which is chromatically excited will induce a consecutive polarity upon that which is neutral, and the neutral object will consequently appear of some complementary colour. It also follows, that the complementary colours must be the most grateful to be viewed simultaneously, because the symmetry of the optic apparatus is then greatest, the chromatic axis is then perfect, and there is no effort to improve it, and therefore no anxiety and dissatisfaction.

All these anticipations, flowing from the principles advanced in this work, are amply confirmed by experience. The simplest case is that in which the propagation of coloured light from a visible object is arrested; but the illuminated state of the optic apparatus continues for some time, in consequence of which, an image of the object lately seen in its true colours remains for a little in a consecutive tint. This may be at once effected, by closing one eye, and fixing the other for some time steadily upon a strongly coloured and illuminated object, such as a red disk of cloth or wafer, lying on a neutral or white bit of paper. Whilst the red light is propagated to the sensorium, the image is red; but if, by closing the eye used, the lumeniferous excitement is made to stagnate in the sensorial ray, that which is on the aspect of incidence, and which, during true vision, was most vigorously excited, continues for some time in the same state of chromatic excitement, wherefore that extremity of the ray directed to the sensorium, must be in a consecutive state, and consequently must produce the sensation of a green bit of cloth or wafer. The result is the same, if we consider only the ultimate atom in the ray which conducts the light to the sensorium; the anterior edge is in the state which produces the sensation of redness; and the other, therefore, must be in the state which produces the sensation of greenness. This experiment is more easily made, by covering the red wafer, after it has been gazed on, with a neutral surface, such as a white sheet of paper, and continuing to gaze. By this means the illumination of the optic apparatus is sustained by neutral light, which does not interfere with the existing state of polarity.

The second case imagined is, when this complementary image, seen when the eye is closed, or turned to a neutral surface, is so strong as to induce consecutive fringes around it. This phenomenon may be readily observed by looking steadily at the setting sun for some seconds, and then closing the eye. Instead of a yellowish-white image of the sun, an ocellus is now seen of some complementary tint, which is a shade of blue, varying as the eye recovers its condition of natural illumination and repose. So far this is a phenomenon analogous to the first case illustrated by the wafer or bit of cloth; but, around this ocellus there is a border or fringe of the consecutive tint, induced by the intensity of the illumination of the central part. If, instead of keeping the eye closed, we illuminate it by gazing at a white sheet, during the existence of the spectrum, it appears that the poles are reversed,—the central ocellus is now a positive tint, and the fringe negative. The same phenomenon may be more agreeably, and more perfectly observed, by viewing a less luminous image when the sensibility of the eye is greater. Thus, by turning the eye newly awoke from sleep to a circular aperture in the window-shutter, when the sun shines on the window-blind, a lucid ocellus will be seen, surrounded by all the tints of the first, and sometimes some of the second, of the Newtonian rings of radiant colours. In this case, the poles are so defined, and separated by so considerable an interval, that the surrounding matter, instead of being induced into consecutive states, like two dissimilar plates of metal, acquires a state of polarization similar to that of an equatorial plate of a crystal to which the lucid centre is pole. In this way, a very good estimate of the relative sensibility of the two eyes may be formed.

The third and fourth cases of the development of consecutive colours in the optic apparatus, are effected also with great ease, and are productive of very curious experiments. That in which both poles are developed from light admitted by one eye, is very entertainingly and minutely described by Count Rumford [*], and his experiments may be easily repeated. It is only necessary to form in one eye two illuminated rays near each other, one of them being coloured, the other, as nearly as possible the same as to quantity of illumination, but charged by neutral light. Thus, let a pencil of light from the sky, whether azure or covered with clouds, it matters not, be received by an aperture in the window-shutter, on a horizontal sheet of white paper. Then, let a candle of inferior quality (so as to give a full yellow light) be provided, and any body to cast a shadow, such as a slip of thick glass, a pencil, or the like. The shadow of the pencil caused by the light of the sky may be examined, by holding the candle above the sheet of paper, so that the shadow due to day-light may be formed in the shadow of the base of the candlestick. This shadow, formed by the light of day, will now be simply black. If, again, the shadow of the pencil formed on the white paper by the candle be examined, the ray of sky or colourless light being intercepted, we shall again find that it is, like the other, colourless and dark. But, if we bring the candle down, so as to illuminate the shadow of the pencil formed by the neutral light of the sky with candle-light, and at the same time to form a shadow of the pencil on the other side, which will be illuminated by the neutral light of the sky, both will seem to be highly coloured. That illuminated by the candle is of course yellow, because this is the colour of the light by which it is illuminated; the other, which is illuminated by neutral and colourless light, gives rise to a ray of this quality, which, at some point in its progress towards the sensorium, comes under the influence of the yellow ray, and, becoming a recipient for the consecutive pole of the chromatic axis, appears of a blue, proportional in tint and vividness to that of the yellow which induces it.

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[*] Philos. Papers, vol. i. p. 319.

Count Rumford found that the same striking phenomenon might be still more beautifully displayed, by preparing two disks, one covered with a highly tinted substance, the other with a white substance toned down, so that the quantity of light reflected from both might be as nearly as possibly the same. Having laid two such disks on the floor of a dark chamber, he illuminated them with a sun-beam. That which was really colourless immediately seemed of a colour proportionally bright to that of the other, and of such a tint that the two united produced whiteness.

Nor is it impossible to develope one pole only in each eye, as has been shewn by Mr Smith. The experiment is still more simple. Thus let a slip of white paper bc taken and viewed with candle-light, while the optic axis is directed to a more distant object. Two images will of course be seen, which, while the state of the illumination of both eyes is the same, will have the same tint. But, holding the slip of paper in one hand, at the distance of about a foot in the mesial plane, let the position of the candle be changed so as to illuminate one eye very strongly, and leave the other as much as possible in a state of natural repose. By this means, the ray from the paper in the strongly illuminated eye is enveloped in a medium strongly excited, and becomes negative, and the image of the paper seen by that eye green; while the ray from the other eye is most favourably situated for giving rise at the region of induction to a positive pole; thus one image is green and the other is red. These phenomena, it will be remarked, are quite analogous to those presented by thin plates.

Such are some of the most interesting phenomena of vision in well organized eyes, when the lumeniferous excitement has been propagated from without. But it evidently follows, from the nature of optic matter advanced in this work, that a similar state of lumeniferous excitement may be induced upon the sensorial part of the apparatus of vision by internal causes, as well as by the entrance of the lumeniferous excitement from the external radiant medium. Accordingly we should expect a variety of spectra to appear as often as the natural and healthy repose of the light of the eye is interrupted by a mechanical or galvanic change in its condition, or in states of fever, or its opposite, or in imperfect sleep; at any time, in short, when that condition of the lumeniferous excitement of the optic apparatus which gives no spectra is changed.

Now, such vision may be immediately experienced by closing the eye, and compressing it: the light of the opposite region is polarized by compression, like a bit of glass; and it is excited by the effort to sustain the circulation, and repair the injury. Accordingly, a coloured ring is seen; the central region, most highly compressed, being a negative tint, surrounded by a bright orange fringe. By rubbing the eye, an effect is produced, as if free particles of light were moving about in its fluids, at the back of the orbit. White light may be developed in vivid flashes, by laying a bit of zinc upon the tongue, and a slip of silver upon the eyelid, or between the upper lip and the jaw, and then bringing the dissimilar metals in contact. In the same way, when the mind is intently engaged about any thing which requires the eye to be illuminated for a long time, this organ is apt to acquire a state of morbid action, and to continue illuminated, when the external source is removed,—the tear flowing over the cornea, of a violet colour in the dark, or the back part of the eye, remaining painfully bright, and appearing as something that is seen, of a form and colour not to be discovered, and so intimately a part of ourselves, that the idea of escaping from it is felt to be vain.

In sleep, and certain diseases, the mind sometimes makes strange use of this internal light. The fact, that this light, when naturally excited so as to produce vision, is always excited in such a way as to produce the sensation of images, must determine a habit in the organ, that, whenever its light is excited, its modes of excitement shall be such as to produce the sensation of images. These images (I do not mean pictures on the retina, but that state of the light of the sensorial part of the optic apparatus, that induces us to believe that we see objects while it exists), as might be expected, generally represent ill-assorted assemblages of things, whose images have been formed in the eye before in a legitimate manner; and it is only an extension of principles already advanced, to suggest, that an image, once developed, should give rise to a second, having a certain relationship to it, the two now existing, to a third, and so on, till the group acquire force enough to occupy the mind, and impress the memory. We have already seen the beautiful manner in which one crystalline form arises out of another, and, though in states very different, yet crystals and the eye are equally composed of similar atoms, which, individually taken, have the same forces and modes of action; and though, during life, these atoms in the eye are in the presence of a spirit, which they serve in the day-time, and which stoops to be entertained by them at night, still it would be unwarrantable to conclude, that the successive evolution of images had not some definite relationship more desultory and varied, no doubt, but no more the work of chance, than the secondary form of a crystal. To this we may ascribe those fantastical structures and unearthly landscapes which we often see in sleep, especially when the full operation of habit is limited more than usual by a feverish state, during which the organic matter is more prone to its peculiar shootings, than in states of health, when repose is the natural consequence of sleep. In this way, every thing seen in sleep is looming. An image of a house or angular body gives occasion to a nocturnal mirage. But as we seldom see a panorama composed of houses only, which we may conceive to be developed by the influence of the first, habit operates for the introduction of mountains, rivers and trees, which are added at that time when the state of the image then existing is most similar to those diurnal images that have been often formed there, and of which mountains, or rivers, or trees, formed a part. In like manner, if the dream originate in the formation of the image of a human body, this will determine the formation of others, either physically, or by the habit of the eye related to the first, and the dream will be developed as before.

In this way, it seems possible to assign a physical cause for the origin and progress of a dream, while the mind is merely an observer, taking a greater or less interest in the scene as the case may be, and remembering what has been going on after we have awoke, with more or less entertainment, according to the quality of the dream.

But there is another class of dreams of a more fitful sort, whose origin seems to be immediately in the mind; and it is most easy to believe, that a perception strongly felt, and having optical images proper to it, should evolve these images or excited spots, in the sensorial matter devoted to such a purpose. We know that our minds act upon matter in some way, and in what way is it so reasonable to conceive that they give rise to atomic movements, as through the medium of light? Now, there is a certain state of the light or radiant matter, in some region of the brain connected with the eye, which gives rise to a certain perception or feeling in the mind as its necessary sequence; and these two events, the nervous excitement, and the feeling, are related to each other as cause and effect. If, then, the feeling be the first of the two to arise, and the materialism be in such a state that the mind modified by the existing feeling can act upon it in an adequate degree, the same connexion of the two phenomena may be expected, though the feeling should be the first of the two in the sequence. It is reasonable to conclude, that the development of the feeling by the mind will induce that same state in the radiant tissue of the optic sensorium, which, when it has been excited by external vision, induces the feeling; and an image thus once developed, will tend to grow in the same way as if it had arisen out of the excited state of the radiant tissue constituting the sensorium, and as if its origin had not been in the mind. But the aspect and grouping of the images of such a dream, will still be modified by the existing disposition of the mind towards a certain tone of feeling. Dreams of this second kind are, no doubt, proper to man, and they are very instructive of our susceptibility of pleasure and pain; for the mind thus frequently, during sleep, enters into scenes of agony or enjoyment, far more intense than are ever experienced when awake.

The theory of dreaming now advanced, would explain why some dreams are connected with the states of the mind immediately preceding sleep, and why others are quite unconnected with it: and as both, though their origin be different, increase by a process perfectly analogous, it would explain why even those whose subjects are connected with the ideas previously occupying the mind, become more and more wayward and unreasonable as they proceed. If it be asked, why ideas do not give birth to various spectra when we are awake, it may be answered, that this is prevented by the optic region being occupied by other images—by the individuality and insulation of the mind being most complete when the man is in his most perfect state—by the greater activity of the process of change and assimilation going on in the cerebral region, which destroys the necessary repose, and requires the stronger stimulus of external light; but, it might also be added, that, in forming a strong and graphic conception of any sensible object, one often finds a sort of image of it before him, especially when gazing upon a neutral ground, which does not excite the eye, and fill it with other images. These investigations, however, belong rather to physiology than physics, and need not be dwelt on longer in this place.

OF THE ACTION OF THE RADIANT MEDIUM ON THE HEAVENLY BODIES.

ONE of the latest opinions which Newton gave was, "It seems to me farther, that the particles of bodies have not only a vis inertiæ, accompanied by such passive laws of motion as naturally result from that force, but also that they are moved by certain active principles." * In this work, it is the latter chiefly which occupy our attention; and it appears that their influence in the radiant medium must produce an effect very different from that of mere resistance to the motion of dense spheres immersed in that medium. They must tend in a high degree to induce rotation in such masses, and consequently progression through the medium. That several causes should conspire to produce one effect, is what we constantly observe in nature. When one artery is destroyed, subordinate branches enough are left to sustain the circulation. Nay, so perpetually does the admirable law of compensation come into play (which is in the material world what justice is in the moral), that we might have been almost safe in concluding, that, if the radiant medium should, in consequence of its density, occasion resistance to the motions of the heavenly bodies, some other feature in its constitution would facilitate progression. Though not proper to the subject of this work, a few remarks could not be avoided in another page on the mechanism by which the heavenly motions are sustained, in which it is assumed that an apparatus different from the radiant is concerned. It appears, however, that the radiant co-operates in a most beautiful manner. At present, we may only regard the planetary bodies as dense masses, possessing forms suited for rotation, and immersed in the radiant medium. Were it to suit any purpose, their rotation might be contended for,

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* Optics, Q. 31.

from the absolute movements of spheroidal bodies in a dissimilar medium; but this need not be insisted on, as the mechanism by which rotation may be *sustained*, can be traced in detail.

The polarity of the illuminated hemisphere of a planet, must obviously be in a consecutive state to that of the dark hemisphere. The radiant medium contiguous to these two hemispheres, then, being merely a conductor of polarity, and not becoming itself polarized in the mass, must be in the same state as that of the planetary surface beneath it. Its position is also fixed. Hence there is a body of a rotatory form with two consecutive polarities on its opposite sides, and these polarities contiguous to poles of another body, which are of the same or a repulsive affection. If, then, one of the poles of the system move any way through the least space, so as to cause the polarized axis of the rotatory mass to form an angle with the radius vector (which is the axis of the polarities of the surrounding radiant medium), this dense body will commence rotation, being moved in the same direction by all the polarities. Each polarised surface is repelled from the region where it is, and attracted towards the region where it is not. Thus the parts of the planet chase each other, the meridian of darkness seeking the meridian of light, and the meridian of light seeking the meridian of darkness. It may be nearer the truth, however, to regard the subtile matter of the planet as circulated, and in this case the same result follows. The opposite sides are in different states, and there must be a circulation as in a spheroidal molecule similarly affected.

If the surfaces of the planets were homogeneous, and the resistance of the radiant medium, from its inertia, (concerning which we have very little information), could be disregarded, the reaction causing rotation, other things being equal, would be proportional to their surfaces. Consequently, the largest ought to rotate the most rapidly, and so on to the least. Those whose rotation has been observed, are thus stated, beginning with the most rapid,—Jupiter, Saturn, Venus, the Earth, Mars, Mercury, the Moon. This is exactly the order of their magnitudes, with the exception of Mars, which, were he illuminated in the same manner as Venus and the Earth, ought to move more slowly. But it is remarked that there is something very peculiar in his illumination.

Now, a planet's surface is by no means perfectly smooth, (the nature of the supernal stratum of a planet will afterwards be noticed), hence, unless the rotating planet meet with equal resistance on opposite sides in opposite directions, its rotation becomes immediately a cause of progression in the same direction in which it rotates. If a sphere of any solid matter be made to rotate, while falling through the air with its poles of rotation more or less horizontal, as soon as it meets the resistance of the ground, it proceeds in the direction in which it rotates, the air resisting it less, and demanding motion in an opposite direction less than the hard ground on which it impinges. Now, this gross illustration is perfectly analogous to the state of matters in the radiant medium surrounding a planet. Between it and the sun the medium is disposed in tense prismatic rays, which even Newton, though under the necessity of maintaining a vacuum, admitted to be in some sense hard bodies. In the shadow, on the other hand, the medium is not disposed in tense rays, and will oppose a much less mechanical resistance to motion. Hence, the planet must tend to proceed in the direction in which it rotates, and as it proceeds, constantly providing itself with a shadow in virtue of its opacity, it is constantly in circumstances equally favourable for progression. Thus, both the physical and mechanical structure of the radiant medium, according as it is in a state of illumination or of darkness, is calculated to sustain the planetary motions. Nay more, the regions of twilight and dawn, the radiant regions that are tangents to the planet, also favour the same movements. For the movement of the polarity, or the circulation on the planetary quadrant contiguous to the rays of twilight, is similar to the direction in which the lumeniferous excitement is propagated from the sun. Hence, as their polarity is the same in direction, they must repel each other.* On the side of the dawn, the lumeniferous propagation from the sun is in the same direction as at the other extremity of the planet's diameter, which separates the dark from the illuminated hemisphere, but the dark region of the planet coming up to the dawn, is in a consecutive state of polarity; hence the polarity propagated from the sun must now operate to draw up towards it the planetary surface meeting it. Thus all things act in harmony—the motion sustains the polarity, this polarity sustains the motion.

Whether James Watt, to whom we owe the condenser, the double stroke, and the parallel motion of the steam-engine, had any idea of such a mechanism, when he named a certain part of his engine Sun and Planet Wheels, may be questioned. One would think that so plain a man would find it difficult to persuade himself that an universal vacuum was the order of nature, when he found that it cost such infinite labour to empty any place of even gross particles of matter, and that really nothing was more obvious than that dense bodies changed into vapour, rather than that a considerable space should be left in the state of purum nihil. But whatever his ideas of the celestial spaces may have been, certain it is, that his sun and planet wheels represent, though doubtless very grossly, the very structure of the radiant and planetary apparatus which has now been presumed as a necessary consequence of the structure of the radiant medium. The rays of light intercepted at the planet are analogous to an infinite number of those radii projecting from a circumference which are formed in toothed wheels and rack-work, and the projections on the surface of the planet are the teeth which meet them. It will afterwards be shewn, that the supernal stratum of a planet presents a mechanism so conformable to that of the rays of light incident upon it, that no language could exaggerate the perfection and symmetry of the manner in which they are applied to each other. Let S be the sun and P a planet, Fig. 32, the suit of the rays which the planet evolves in the course of a revolution is represented by a circular, or more strictly an elliptical system of radii, of which the sun is the centre, and the planet always in the circumference.

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* The case is analogous to those experiments of Arago, in which electric currents are sent along two parallel wires, in opposite directions, from which it must follow, that the external currents, at right angles to the axis of the wires, must be in the same direction at any point where the wires can be brought near each other.

The structure of the radiant medium, then, may aid the planets in their progression; but this is not the principal cause, for if it were, then hourly motions in their orbits ought to bear some proportion to their velocity of rotation, which does not appear. Mercury, whose rotation is the slowest, is hurried round the sun with an hourly progression between three and four times that of Jupiter, which rotates most rapidly. There is a continual retardation in the velocity in the orbits, as they are more and more distant from the sun. It is the only phenomenon in the planetary system, except the direction of rotation, in which uniformity and continuity of change is observed. Meantime, enough has perhaps been advanced to apologise for the action of the radiant medium upon the motions of the planets, and to dispose the reader to regard it with less dislike than if this subject had been wholly passed over.

OF RADIANT HEAT.

Almost all the phenomena in physical optics which we have lately considered, are purely the discoveries of modern times; the chief of them belong to the present century. Our age has been much less happy in its inquiries respecting radiant heat; more moderate views will be found in the ancient than the most modern philosophers. Many of their statements respecting fire, taken by themselves, are singularly true; and though these opinions be but insulated communications, often derived from very false reasonings, still they are truths. Though they be but lucid intervals in the midst of very deranged notions about the nature of things, still they are entitled to our regard, and, in the history of science, ought not to be forgotten. It becomes posterity to treat sacredly, as if they were their monuments, whatever truths can be gathered from the physics of the ancient philosophers. The wonder is not that they, but that we, should be so often wrong. There is, perhaps, more that requires to be forgiven in the tenets of the philosophy of the nineteenth century than of that of Pythagoras or Plato. Plato makes Timæus say, that he thought it probable that the form of fire is the pyramid; and whatever may be thought of the reasoning by which he concluded that it was so, or his notions regarding fire, that cannot alter the truth which he announced. Although, therefore, it was perhaps by a more humble and tedious process that this form was assigned to the igneous atom, which has given a basis to this work, this view has little higher pretensions than the revival of an ancient opinion, which has been regarded since the revival of learning as one of the vagaries of the fancy of the Pythagoreans.*

In all that has been advanced respecting the phenomena of light, it has never been assumed that the radiant medium is any thing else than a very attenuated mass of matter, differing from other masses in form and attenuation only. Its specific repulsive fluid is *light*, and in the elastic tremor of its solid nucleus, according to the view which has been already advanced, its *heat* consists.

As a member of the universe, every body possesses a specific quantity of atomic tremor, depending upon the substances to which it is contiguous, and its aptitude for sustaining a tremulous state. This quantity is its specific heat. It will afterwards perhaps form one of the finest occupations of geometry, to calculate the specific heat of particles of bodies, derived from the aptitude of their forms for vibration; meantime we will rest satisfied with the opinion, that forms which are least symmetrical, and have their axes lying in different directions, are least fit for sustaining calorific excitement. If this be the case, the atom will possess a very small specific heat, or, when once excited, will very readily part with its heat to contiguous cold bodies. For, if any angle be made to vibrate by the influence of a hot body, there is not another opposite to sustain the elastic tremor, and respond to it. The vibration is not symmetrical on opposite sides of the centre, and when one angle has been heated, the action of the other three upon it may be compared to the phenomena of interference. The pungency of its angles, however, is greater than that of any other form; a free atom may therefore be made excessively hot, and in consequence of its incompatibility with a sustained state of tremor, when the source of excitement is sustained, it will communicate heat with great rapidity, and excite violent burning in the gross bodies which receive it. Viewed, then, as a member of the universe, the specific heat of the radiant medium will be very small. But, from the extreme minuteness of its atoms, the symmetrical relationship of the angles of contiguous atoms or rays, and the very small quantity which it can absorb on its own part, the radiant medium is better calculated than any other medium for conducting calorific excitement from a hot body to a cold one. This effect will be produced by a radiant action analogous to that by which light is propagated; nor can it take place to any great extent, without a simultaneous excitement of light, which we might naturally expect to amount to such a quantity as to affect our eyes. When an atom of radiant matter contiguous to a hot body is heated, its tremulous state must be immediately communicated to the elastic subtile matter which surrounds it. But this subtile matter is in contact with the subtile matter of the contiguous atoms of the radiant medium. And, in consequence of their mutual elasticity, the tremor must be propagated towards their centres, exciting the atomic nucleus into a similar state. Thus the first degrees of radiant heat may be propagated apparently in a mechanical manner, and without the necessity of a considerable change of place in the radiant atoms. But, as the heat is urged, a difference in physical, and consequently lumeriferous state, will belong to atoms dissimilarly heated. Hence, if the radiant medium, by the proximity of dark cold bodies, be relieved of its change of heat, rays will ultimately be instituted perfectly analogous to those produced where lumeniferous excitement, not calorific, is the moving cause.

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* See Note B.

From the superiority of our thermometers to our photometers, we are now able to prove what was already advanced, that radiation does not proceed at random, and equally on all sides, without regard to contiguous bodies, but with far greater intensity in the direction of such as are in the most dissimilar state. Thus, let two thermometers be taken, both at the same temperature, as, for instance, zero or 100°, the temperature of the ambient medium being 50°; and that they may more powerfully act upon each other, let them be placed in the conjugate foci of a metallic reflector. In this case no radiation will take place between them at all, and (if both possessed less than that specific heat which they would retain if cooled down from a maximum,) in a state of insulation in space, they would remain at the same temperature for ever. But, let one of them have a hundred degrees of heat, and the other be at zero, and then let them be placed in the foci of the reflectors, and a powerful radiation is immediately instituted, and they speedily arrive at the mean temperature, which is not far from 50°.

Analogous phenomena are presented to us in nature, contributing in a wonderful manner to uphold the economy of creation. Tropical climates have less need of a powerful solar radiation than arctic climates, and the circumstance that the temperature of their surface is much higher, diminishes the rigour of the solar radiation in a very remarkable manner. The experiments of the Rev. Mr Scoresby and others in the Arctic Regions, shew, that, while the temperature of the air in the shade is below the freezing point, the heat caused by solar radiation is sometimes between 120° and 130°. On the shaded side of the ship ice sometimes formed, while on the sunny side the pitch melted under the sunbeam. The experiments of

Captain Sabine, on the other hand, at Sierra Leone, and in other tropical regions, which he has visited and examined, shew, that, instead of a hundred degrees of difference, there is often little at all, and never any amounting to a half of that of the Arctic Regions. The same fact enables us to account for the very powerful and vivifying influence of the sun in spring, when the surface of the earth still retains the chillness and cold of winter. It also explains the fact, that the calorific radiation from the earth is strongest during the warmest weather. When there are no clouds in the atmosphere to act as screens to ethereal rays conducting or radiating heat from the earth, and when, by the influence of the sun during the day, its temperature has been raised above that of the radiant canopy above it, the terrestrial heat is rapidly carried off, and a great depression of temperature ensues. It is commonly believed that these rays are continued indefinitely in straight lines, perpendicular to the radiating surface, and the phenomena of dew are believed to afford one of the best illustrations of the hypothesis of indefinite radiation into space. Perhaps the radiant medium above, which is more than any other body disposed to become cold, and the sky, of which I shall afterwards speak, are the directions taken by the radiant heat. But, when we consider that the radiant medium over different regions, like the atmosphere, possesses different degrees of coldness, and that the calorific excitement propagated upwards, will, in consequence of the greater ease of transmission, always seek towards the coldest parts; as it can descend with the same facility as ascend, it seems more probable that the heat radiated from warm places of the earth in clear nights, after penetrating through the clear air to a certain elevation, comes under the influence of the cold rays, emanating from cold regions of the earth, more or less contiguous, and is propagated downwards towards them. This is merely an application of the views already advanced respecting capacity for heat. A hot ray of radiant matter terminates in two, one of which is cold, and the other hot, and it is conceived that a greater quantity of calorific excitement is propagated along the cold than the hot ray, because its capacity for receiving heat is greater.

Bodies are heated and cooled by ethereal conduction with very different velocities. Other things being the same, we should expect that the process, whether of radiation or absorption, that is, of becoming cold or warm, should go on with a velocity proportionate to the number of radiant atoms in contact with a given extent of surface, and this seems to express the phenomena with sufficient precision. Thus, of all common bodies, lamp-black contains the greatest number of free particles on a given area, for the particle of carbon, as we shall afterwards find, is exceedingly small. Now, this substance gives off and absorbs radiant heat more freely than any other which has been tried. Other bodies, too, whose substance is composed of particles of hydrogen, carbon, silicon, oxygen, and nitrogen, are also remarkable for their great radiating power; and if they were reduced to the same mechanical condition of surface, probably some very marked analogy would be found between their relation to radiant heat and their chemical constitution. But in the state in which they have been examined, the amount of radiation and absorption must have been mainly regulated by the condition under which the body was exhibited. A surface which, when smooth, makes only a weak exchange with the radiant medium, cools or becomes hot much sooner when its surface is ruffled or furrowed by parallel lines. In this case not only is its surface increased, but the parallelism of the lines is analogous to that of the radiant edges, and will admit of the access of the radiant molecules symmetrically. But not only are there differences as to the number of points and projections which different sorts of substances, having the same chemical composition, offer on the same area, so as to modify the quantity of radiant atoms in contact with them; there are many bodies with which radiant matter cannot come in contact at all, and with which its exchange of heat must be extremely slow. Of this sort are all those bodies which possess a stratum of free light upon their surfaces, which is indicated by their very high refractive and reflective power. Of these the laminated and polished metals are the chief. Every one has had occasion to remark that, whilst a hot fire is in their immediate vicinity, the polished brass of the fender and fire-irons remains remarkably cold, though the action of the fire, at their distance, upon the hand be very considerable. The same aversion to sympathize in the temperature of the ambient medium is shewn by the great length of time which vessels of silver, brass, or planished tin, retain warm water, without suffering it to cool otherwise than by its own evaporation or radiation from the surface of the liquid. Were the metals, however, not in that state of great compactness in which we are necessited to examine them, probably no such very marked results would be observed.

Since heat is an affection of the same atoms as light, and gives rise, though not always in the same degree, to the same motions, it follows that it must observe the same laws as to reflection, refraction, and singling, though the same body may, in consequence of the perfect difference between heat and light in themselves, act very differently when reflecting the one or the other. Thus, a metallic mirror will reflect both lumeniferous and calorific excitement very freely, but if it be covered on the reflecting side by a glass surface, the radiant atoms will impart their calorific excitement to the glass, and be cooled there, so that the lumeniferous rays reflected from the mirror are now comparatively cold. The heat is mostly given off to the glass, which is a body composed of very small particles, as will be afterwards shewn.

There is no reason why a transparent screen, or glass surface on a metallic mirror (for it is all one) should transmit radiant heat rather than an opaque one. If the radiant atoms conducting the heat be in a state of lumeniferous excitement at the same time, then the transparency will be of avail in continuing the same state of thermo-lumeniferous excitement on the other side. But where the radiant excitement cannot be propagated after the manner of light, but simply as an atomic tremor, those screens would transmit heat most easily which conduct it most easily, and all such bodies happen to be opaque. Radiation is merely the conduction of heat in the radiant medium, and those screens will be most permeable to radiant heat which permit the closest contact of the greatest number of radiant atoms, and transmit the tremor through their own substances most rapidly. The transmitting powers of two screens can scarcely be compared together; for unless a clear glass one and a blackened glass one have the same disposition to radiate heat themselves, that which radiates back the greatest quantity (which is so much lost), has obviously the smaller remainder to transmit; and if two screens do not admit the ethereal contact equally, that will transmit the greatest quantity to which the greater quantity of radiant matter is contiguous. Unless the symmetry and structure of two screens be mechanically the same, they cannot be compared.

Transparent and opaque screens transmit radiant heat in the same way, that is, by those fibres of their own substance becoming heated on which the hot radiant atoms are incident. But, when the heat is urged so as to excite the subtile fluid of the radiant atoms, so that they are in a state of thermo-lumeniferous excitement or fire, in virtue of its luminous nature, it may now be transmitted along the lines of transparency of the screen, and continued in the same state of calorific excitement on the other side. Without succeeding in inducing an equal degree of heat in the screen through which it is transmitted, it may induce a high degree of calorific excitement in the ethereal rays on the farther side of the screen; for the lumeniferous excitement which is transmitted, originated in a certain thermo-state of the solid matter of ethereal atoms, and when the thermo-lumeniferous state is induced (by transmission) upon the subtile matter investing the ethereal atoms on the further side, its immediate reaction upon their solid nuclei is to induce the state of atomic tremor proper to the existing state of excitement of the subtile matter.* From a very hot body, then, different sorts of hot rays will be emitted towards cold bodies, depending for the intensity of their heat on the hotness of those points of the hot body on which they are incident. By interposing a transparent screen, they will be separated: those in which the calorific excitement predominates over the lumeniferous will impart all their heat to the screen, or be reflected or radiated from the side most contiguous to the hot body; but those which are sufficiently lumeniferous to be propagated in this capacity, will penetrate screen after screen, with only small losses compared with that thinning which takes place at the first screen.

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* This mode of reasoning is analogous to that of p. 161.

The hot light which is thus transmitted, differs from cold light in its movements and condition. Its subtile matter, not less than its atomic matter, vibrates elastically around the centre of the atom which, in reference to this motion, is quiescent. But the atom also vibrates as a whole, the centre performing excursions on both sides of its mean place. It is not difficult to conceive that light, in this tremulous state, may be propagated through a transparent screen, without making it so warm as the radiant medium on the emergent side; for the atoms of radiant matter in the substance of the screen may be so bound on the angles, that their vibratory or calorific excitement is difficult. This restraint will allay the tremor of the subtile fluid investing them immediately after it has excited a similar state in the next contiguous atom in the course of the ray, and thus the tremulous light will be transmitted in pulses with intervals perhaps of common light. But, when the tremulousness gains the other side, there is no impediment to the vibrations of the atomic matter of the radiant medium; it will therefore be immediately induced by the tremor of its investing subtile atmosphere.

With regard to the amplitude of the excursions of these particles of fire, it seems to follow that they are larger than those of common light. For though the tendency of matter to expand as far as possible, would lead us to infer that the angles of an atom are at their greatest distances when that atom is quiescent, and that heat is in fact a *conatus* of the atom to become spherical, still the depth of its repulsive fluid must be expanded, in consequence of the exhilaration by heat. As the temperature of the hot body is urged, however, the rays become more eminently lumeniferous; the chemical or electrical action prevails over the mechanical or calorific, and many of the rays emitted approximate in their nature to common light. This is particularly the case in combustion and flame. In every instance where these phenomena occur, there is a change in the equilibrium of the radiant contiguous to the combustible. In ordinary cases, indeed, as will afterwards be shown, wherever a combustible body is burned, an atom of radiant matter is set free by every particle of oxygen which is consumed, and, added to the radiant medium in its state of excitement, it naturally gives rise to a ray of light.

But all the radiant light and heat that are generated by combustion, or otherwise, are little to be considered, compared with that which emanates from the sunbeam. When the flame of a very bright Argand lamp is placed in a field of snow, it seems merely a dim yellow object, which one would not suppose to be flame, and if held up between the eye and the sun, it becomes invisible altogether. To shew even vivid combustion with any effect as a luminous object, it is necessary that the chamber be darkened. Even the diffuse light of day is incomparably more powerful than any light that can be artificially excited.

The light of the sun is well known to be accompanied by a very considerable power of heating every body on which it is incident. There are remarkable differences, however, according to the body's action upon light. Those substances which are covered by a stratum of light (which prevents the contact of the radiant atoms) restrain the calorific action of the sunbeam the most perfectly. Bodies with a high lustre consequently remain cool in the sunbeam; white bodies are most difficultly heated, black most easily; and intermediate colours resist the calorific action of the radiant medium by which they are illuminated, in proportion as they reflect a larger quantity of the ethereal rays incident. These are necessary consequences of the structure of the solar ray, and the variety of facilities which different bodies afford to the percussion of the radiant atoms on their solid substance, and they are abundantly confirmed by observation. A bright metallic mirror remains very cool for a long time, whilst a sunbeam is incident upon it, and while the sun's image in the focus is warm enough to melt flint in a moment. But if the mirror be covered, even by a very thin pellicle of smoke, instead of reflecting to the focus the solar rays incident, it immediately proceeds to become warm itself. The action of radiant heat is beautifully described by Boerhaave in his chapter De Igne, which is worthy of being named along with the Opticks of Newton. The effect of colour is also easily seen, by exposing patches of the same sort of cloth, but of different tints, upon a surface of snow. The heat which they receive melts the snow beneath them, and they sink below the level of the surface, according as they absorb more and more of the solar ray. Aware of this power of black bodies to aid the sun in melting snow, the inhabitants of some valleys of Switzerland, sprinkle the snow-covered gardens with black earth, in consequence of which the snow disappears more rapidly. Analogous phenomena are presented in the giving out of heat by bodies of different colours, when the incident radiant matter is illuminated. Thus, if a lock of white, and another of black wool be exposed to a clear sky, in the shade; during the day-time, the black lock will continue the colder of the two, as, from the radiant contact which it permits, it parts with its heat more readily to the sky; but during the night, when they are equally black, both are equally cold. Hence, we may say, that whiteness insulates a body in the day-time, and makes it more dependent on itself for its temperature, while blackness makes it quite contiguous to the radiant medium, and causes it to partake with ease in all the variations of radiant temperature. White dresses are, consequently, the warmest in all cases, when the heat caused by the solar radiation is under the temperature of the body, and a white fur or plumage is much better adapted to a brumal period than a black one. But for inanimate objects, such as walls for fruit-trees, a black colour may be much warmer than a white one; for a black surface absorbs far more solar heat during the sunshine, and in the absence of day light, both the white and the black must radiate much the same, if they do not differ otherwise than in colour. These phenomena enable us to see the admirable harmony of effects which arises from a change towards whiteness, in the covering of animals in brumal and arctic climates, during the snowy season. For, not only is their colour thus assimilated to that of the ground on which they must exist, as it was during the summer, and thus the same risk of destruction from predaceous animals incurred, and the balance of species sustained, but their whiteness performs the same part, in reference to the radiant medium, that the oil on the plumage of sea-fowl does in reference to the water. It prevents them from being wetted by the cold.

Whence comes the heat of the sunbeam? Does an ethereal ray become hotter as its parts are nearer the sun in the inverse ratio of the square of the distance? Such an idea leads to very extravagant notions as to the temperature of the sun, and the coldness of the more remote planetary orbits, and, were it true, would form an exception to the law of compensation, which we find everywhere operating, whose function is to produce a mean result, a deficiency in one factor being supplied by the abundance of the other.

Supposing no exchange of heat to take place between the heavenly bodies, each must possess a specific heat proper to its matter, which will be the sum of the different specific heats of all its substances; and the quantity of specific heat belonging to each, supposing it homogeneous, will be proportional to the number of atoms it contains, that is, to its mass. If, then, we suppose all the members of the planetary system to have had at first their matter in the same state, the quantity of specific heat possessed by each will be represented by its mass; but, previous to any excitement or loss, the temperature of their surfaces must be the same. It follows, however, that sustained pressure upon a mass possessing a certain specific atomic tremor, or heat, must directly go to diminish continually the quantity of that tremor, by diminishing the spaces through which the angles of the atoms may vibrate. But such an effect must immediately be indicated by a rise of temperature, or a disposition to communicate heat to other bodies, whose circumstances are more favourable for entertaining that state of motion which the compressed body is necessitated to part with. Phenomena such as this are constantly exhibited. When air is compressed, the containing vessel becomes hot; and in rolling and compressing metals, the whole apparatus often becomes exceedingly warm. The capacity for heat proper to the body suffering compression, is continually diminished by that compression; but, previous to its compression, its capacity was supplied by its specific heat; when it suffers a diminution of capacity, therefore, heat must be given off to surrounding bodies. The capacity and specific heat of those strata of planetary bodies which are not superficial, and are suffering compression by such as are incumbent, must therefore be suffering a continual diminution. This heat, expelled from the stratum now suffering compression, cannot be propagated towards the centre, for the inferior strata being compressed by a greater weight, are less fit for entertaining it than that now losing its capacity. The heat must, therefore, proceed towards the circumference, and will appear on the surface as temperature, that is, a greater degree of heat than that which is proper to the contiguous body which has been long in contact with it. From this, it appears that a process is going on by which heat is constantly propagated from the interior of a planet towards the superficial parts. Nor is the process sudden or volcanic, but slow, like the progress towards quiescence of an elastic and sonorous body; and it is evident, that, if the mass of the planetary body be great, and its quantity of specific heat consequently great, from this action of the weight of the superior strata, an immense degree of heat may be conducted towards the circumference for an indefinite, but not infinite, number of ages.*

For this, however, it is necessary that the surface be relieved of its high temperature by colder bodies; for, were this not to happen, the superficial atoms, sustaining a very great heat, would be in a state of constraint as great as the inferior atoms compressed by the column above them,—the heat of the incumbent strata would attenuate their attraction, and, consequently, their gravitating energy would be proportionally diminished, and the compression and peripheral propagation of heat would cease. Supposing all the planetary bodies of equal antiquity, insulated in space, and composed throughout of homogeneous atoms, this view would assign to them superficial temperatures proportional to their masses. But differences would soon arise to modify such a state of things, and each would have a specific character in the heat of its superficial strata, as it has in the other elements of its physical condition. None of the planetary bodies is insulated. All of them are immersed in the radiant medium, which, considered as a mass, certainly possesses some power of relieving a surface of its heat, though we cannot ascertain to what amount. But to whatever extent this calorific excitement in the radiant matter around a star or planet may extend, there can be no doubt but, considered by itself, it decreases as the square of the distance increases. According to this view, then, the calorific energy of planets or stars, considered merely as sources of heat, is also, like their lumeniferous energy, expressed by

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* "Do not great bodies conserve their heat the longest, their parts heating one another; and may not great dense and fixed bodies, when heated beyond a certain degree, emit light so copiously, as, by the emission and reaction of their light, and the reflections and refractions of its rays within their pores, to grow still hotter till they come to a certain period of heat, such as is that of the sun? And are not the sun and the fixed stars great earths, vehemently hot, whose heat is conserved by the greatness of the bodies, and the mutual action and reaction between them and the light which they emit, and whose parts are kept from fuming away, not only by their fixity, but also by the vast weight and density of the atmospheres incumbent upon them, and very strongly compressing them, and condensing the vapours and exhalations which arise from them?"—*Optics*, Q. 2. Newton's mind, as displayed in his Queries, compared with his Principia and Optics, reminds one of those beautiful fireworks which first ascend aloft like rockets, but without noise and scintillation, until they have attained a most sublime elevation, after which they are for a moment stationary, when they break, dispersing around a multitude of beautiful little lights, wanting unity and direction, indeed, and even pursuing opposite courses, but all of them very beautiful, like the grand globe out of which they sprung.

$$\frac{\textit{the mass,}}{\textit{the square of the distance.}}$$

We can easily conceive a chemical phenomenon, such as the propagation of light, to be extended from one body to another to an indefinite distance; but we should infer, that a mechanical tremor of solid atoms, whose solid parts are not in contact, would speedily become evanescent. The very inequality of the contiguous vibrations, must constantly give rise to interferences, and coldness must ensue. In as far as the radiant medium is concerned, then, and this is all we have to consider, every planetary body may be regarded as more or less completely insulated. The superficial temperature of the planetary bodies, supposing them constituted of atoms originally homogeneous, and, in a similar state, must then for a time have been rudely represented by their masses, (disregarding their satellites); but the departures from this state of things are, no doubt, very great in our age, in consequence of the great variety of mineral bodies which may have been developed as the temperatures, and consequently the balancing of the attractive and repulsive principles were different. But without pressing the argument farther than our data permit, it will be granted that it is much more easy to see how a temperature may exist at the upper limits of the sun's atmosphere, adequate to throw it into that state of splendid lumeniferous undulation which we behold, than that it should be too cold there for such a purpose. The actual quantity of heat, however, proper to any atom or mass of atoms, will decrease as we descend towards the interior, or as the supernal pressure increases; nor can we say, whether or not some inferior stratum may not have long since attained a state of absolute stillness or coldness. Indications among the superficial strata of the action of heat from beneath, do not necessarily indicate a state of higher temperature at the central parts; but rather that these parts have already lost a quantity of heat proportional to that from which their central heat is inferred, the superficial heat noticed being nothing else than that which they have given out; and we cannot conceive any cause to restore it to them again, but the cooling of strata still more deeply seated. For explaining all the phenomena of solar and terrestrial heat, however, it is not necessary to assume that their central parts are or ever were composed of homogeneous atoms, possessed of an adequate specific heat. A stratum of such atoms extending to a certain depth would be sufficient, and that such has really been the case will, I trust, appear in the sequel of this work. The intrinsic temperature of the surface of our earth must be comparatively very low; but, the solar influence included, it may be stated, that it is that of water under a pressure of 15lb. on the square inch; for in relation to water our world is organized. Now, though the idea be gratuitous that water should be found in the sun, this might take place though that ponderous sphere possessed a temperature immensely superior to that of the earth. The boiling point of water depends entirely upon the pressure upon its surface. The pressure of the air removed, the heat of the hand is sufficient to cause it to boil very rapidly; while, by exposing it to great pressure, it appears to have remained in the state of water when the vessel containing it was red hot. If the pressure of the atmosphere of our earth, then, retain water in the liquid state till it attain a heat of 212° Fahr., or 100 cent., the pressure of the sun's atmosphere, which surely will be a very extensive one, may retain water on his surface in a liquid state, though the bed of his ocean were as hot as any one can suppose. Besides this, the increased gravitation of the aqueous particles themselves, may confine it to liquidity at a temperature far higher than we might readily imagine.

These suggestions, however, are merely curious, and are introduced to shew, that, before we can assert, that, at such or such a temperature, substances will be in certain conditions, all things must be considered. To speculate concerning the physical condition of other planetary bodies, is one of the most refined researches of Natural Philosophy, and not to be attempted by every one who wishes to know whether there are men in the sun and moon.

The arguments which have now been advanced to establish the vulgar opinion that the Sun is superficially very hot, and may continue to be so for an indefinite time, goes to assert, that the Moon, as to her intrinsic temperature of surface, must be colder than the Earth. The quantity of her specific heat is less in the ratio of her mass. Her compressing or condensing force which developes the superficial heat, is also less in the same ratio; and her surface, from which heat will be radiated, is much greater than that of the earth in relation to their bulks. All these circumstances should tend to make her intrinsically colder on the surface, which her rather smaller density, indicative, perhaps, of a greater internal specific heat, would not be able to balance. All the phenomena seem to countenance this idea. The coldness of moonlight is a common remark, which ought to follow if she is really cold; for, according to the common phenomena of radiant heat, the immediate effect of the coldness of her rays would be to abstract heat or produce cold in terrestrial bodies exposed to her beams. This view seems also to be countenanced by the fact, that her image, in the focus of Vilett's mirror (in which the sun's image fused flint in a moment,) though intensely luminous, was as cold as the ambient medium. But if she be much colder than the earth, one of the phenomena most immediately resulting will be, that the water on her surface must only exist as ice, and therefore she can have no seas. Now, on the whole of her hemisphere which is visible to us, and with which we must content ourselves, there is no extent of surface sufficiently smooth to admit of the supposition that it is liquid, and the very glacial aspect which she presents in the telescope, are all favourable to this view.

But even supposing that the intrinsic temperature of the planetary bodies is represented in a rude way by their masses, and, consequently, that the superficial heat of the sun is very great, it does not follow that his heat is directly the cause of the heat of the sunbeam. To suppose this, would, indeed, be to assume nothing more extravagant than is usually done; and it might be supposed that ample provision has been made already for a temperature of the sun's body adequate to radiate a heat, which, at our distance from him, shall still possess all the intensity of the fire of the sunbeam. But, as has been already stated, it is difficult to conceive how a mechanical tremor, whether of the atomic or subtile matter of the radiant medium, decreasing continually as the distance increases, could be propagated to such extreme distances. That it must decrease in the course of any one ray, follows from the expansion of the intervals between the rays, which remain quiescent. Unless, then, there were an aliquot synchronism between the movements of contiguous atoms, their movements would interfere, and coldness would result, and thus along the course of a ray perpetual stoppages would occur to the continuous propagation of solar heat.

The undulatory theory of light has, indeed, familiarised our minds with notions as to a perfect mechanical elasticity; and if we could receive, that a wave of radiant matter may be mechanically propagated from a fixed star like a wave of water on the surface of a lake, it will demand but a small effort to believe that the mechanical tremor of the elastic matter of the radiant medium, at the surface of the sun, is propagated as far as the earth. But we find very little countenance for the belief of such perfect elasticity from any terrestrial phenomena, and by these it is right to be guided as often as possible. If we were to suppose, as is commonly done, that the heat of the sunbeam incident on the earth, were continued in an increasing ratio, as the inverse of the square of the distance, the temperature, even at the distance of many comets' perihelion passages, would be greater than any thing we can conceive. Newton calculated, that the heat which dry earth, on the surface of the comet of 1680, while at its perihelion, must have conceived from the rays of the sun (on the supposition that heat increased according to the law that has been mentioned) was 2000° hotter than red hot iron! This assigns a temperature to the sun which is quite inconceivable to belong to matter under any form in which it is known to us. We are not necessitated, however, nor even at liberty, to entertain such ideas. The phenomena countenance the view, that the heat of the sunbeam at the earth, (except in as far as an atomic tremor, of a certain quantity is proper to the transmission of solar light,) is, in reality, excited only by the impact of these beams upon the solid matter of the earth. A ray of white light, illuminating a surface, is like a hammer in the centre of a spiral spring, performing nearly 458,000,000,000,000 strokes in a second, the central part coming in contact with the surface struck as many times every second.

Such a continuous percussion must certainly excite the heat of the stratum of atoms on which it is made, and the heat then generated must be propagated upwards along the ray towards the sun, and downwards into the substance on which it is incident, and the effect resulting seems adequate to account for all the temperature generated by the sunbeam. It makes it to depend however, on the intensity of the lumeniferous action of the sun; and it is remarked, that in arctic regions the extreme force of the solar radiation is accompanied by a proportional brightness in the sun's rays; while, in tropical climates, though the lumeniferous excitement were even greater, the calorific action would be less effectual, in consequence of the greater heat already existing in the surface on which the sunbeam is incident. This view also makes the temperature of the sunbeam depend upon the resistance to its continuity by some opaque body, and certainly all the phenomena are favourable to such a view. Thus, a pencil of rays may be made to converge to a focus, by a mirror, or lens, and out of this focus, though, in its immediate vicinity, not the least heat can be detected; but, in coming in upon the sun's image, which will be constituted there as soon as any body is placed to receive it, such a fire is generated as to fuse flint. This heat in the focus, as appears from the experiments of Count Rumford, is, as we should expect, greater than that in the unreflected sunbeam, in the proportion of the greater number of rays impinging on the same area.

It has been already assumed, that the density of the radiant medium increases as we ascend in the atmosphere. The solar radiation, therefore, ought to produce a greater heat from this cause, not less than from the more intense lumeniferous excitement; now the observations on the heat of the sunbeam on lofty mountains, prove that it developes more heat when incident on an opaque body, than in the plains below. It ought also to happen, that if a very small body were completely insulated, so as not to lose its heat by radiation or conduction, it ought to become extremely hot in the sunbeam, in a ratio faster than the decrease of its mass, the form remaining the same; and in accordance with this view, Professor Robison found, that a thermometer laid on cork and down, (which do not cool bodies much by becoming warm themselves,) and insulated in a glass case, arose, in a summer day, to 237°; and Saussure raised the temperature of a piece of burned cork considerably above that of boiling water. By conducting these experiments with a very minute apparatus, perhaps results of a very surprising nature might be obtained, and such as would throw much light upon vegetable physiology. We can form no idea as to the temperature which certain molecules on the leaves of plants may attain in the sunbeam. Thus the particles on which their colour depends are enclosed in cells, where there must be perfect stillness, in as far as the external agitation of the atmosphere is concerned, and they seem to be attached only by one point to the walls of the cell. These walls are laminæ far more attenuated and unfit for conducting heat than down; and the processes of assimilation which go on there, may be conducted at a temperature far higher than we might on first thoughts imagine. It appears, then, that between the sun and the earth a calorific axis must exist, having its neutral point, or points, where the heat of the ethereal ray is the same as that proper to radiant matter simply lumeniferous in some point between them, and nearer to the earth than the sun, in proportion as the heat of reverberation at the earth's surface is less than the heat propagated from the sun, in consequence of that proper to him, or excited by the percussion of the radiant medium upon him; and, in like manner, it seems to follow, that there will be some point in every lumeniferous ray where the calorific excitement will be a minimum, and equal to that of the ambient radiant medium. It is difficult to conceive, if the radiant medium in the celestial spaces, were actually heated by the sun, why it should be cold during the night, for we cannot suppose the heat of a body in the gaseous state (which, of all the others, is the most retentive of calorific excitement,) to be lost like its lumeniferous excitement, in a few minutes after the removal of the source of heat. We find, however, that a propagation of heat from the earth upwards, indicative of cold in lofty regions, goes on from the time of the maximum temperature of the day, and increases with extreme rapidity after sunset, producing such a degree of cold that there is scarcely a month in the year, in this climate, when the surface is not subject to be cooled down to the temperature of hoar-frost, though the climate be such as to ripen wheat of the very best quality in September. According to the view now advanced, the heat of the sunbeam is merely a temperature developed by the percussion of the base of the rays on an opaque body, and depends, for its quantity, on the quantity of percussion which the body admits. What the degree of heat proper to the sunbeam, in consequence of the movements of the radiant atoms during the transmission of light, may be, we cannot ascertain. Admitting that the transference of lumeniferous excitement is effected, without an actual contact of contiguous edges, the heat resulting from the motion can only be excited through the medium of the subtile matter; and how far such subtile tremor may be compatible with that continued change of form which it must undergo, in passing from the negative to the positive, and from the positive to the negative state continually, it may be difficult to ascertain.

The heat of a ray (considered apart from its action upon the subtile matter, as a cause of evolving light) must be adverse to the propagation of lumeniferous excitement. The light emanating from a luminous body can decrease exactly in the inverse ratio of the square of the distance, only when the radiant atoms conducting it are equally cold or hot, along the whole course of the ray. If it be hot at one part and cold at another, not only is its symmetry somewhat destroyed, but the parts differently affected by heat, acquire, to a certain extent, opposite polarities, and thus the perfect induction, on which lumeniferous propagation depends, is impeded. If the heat of a ray of light, then, decrease as the distance from the calorific and luminous body increases, (which, in those cases where the heat of the ray is derived from the luminous body, must be the case,) the cold, or distant parts of the ray must be more highly luminous than those where the temperature changes rapidly; and, consequently, where the recipient of the lumeniferous excitement remains the same, the intensity of the light ought to diminish in a lower ratio than that expressed by the inverse of the square of the length of the illuminating pencil. But, in all cases, it is reasonable to suppose, that a rod of radiant matter, like that of any other substance, is colder in proportion as it is more distant from the flame which warms it, or the extremity in the furnace. Now it appears, that the light of lamps and candles, on which only experiments can be made, does not decrease at different distances so fast as the common formula assigns to it, even though it must traverse the air, which cannot be altogether transparent, and which ought, therefore, to cause the light in such a medium to decrease faster than this ratio. Thus, it follows, from the admirable experiments of Count Rumford, instituted with a view to discover the amount of absorption which light suffers in passing through air, that, instead of an allowance for loss of light, supposing his own formula to be strictly true, there is actually a greater light than the formula assigns, disregarding the obscuring effect of the air altogether. He first made use of two wax candles, placed close together, at a certain distance from the field of his photometer, an equally intense shadow being obtained from an argand lamp at a distance. One of them was then extinguished, and the other brought near enough to balance the shadow of the lamp, which remained stationary; and this took place in the mean of five experiments, not when the one candle was at half the distance of the two. The squares of the distance were not as 3251.09 (the square of the greater distance) to 1625.54 its half, but to 1682.61; so that, if we suppose the two candles to be at the distance of 100 inches from their shadow, one will give an equally good shadow, not at the distance of 50, but 51.45. He then varied the experiment, substituting lamps for wax candles, in consequence of the greater stability of their light. In this case, the apparatus was not quite so favourable to accuracy, in consequence of the difference in the two lights employed, one of them giving far more light and heat than the other. Still, however, the actual distances generally came out, possessing the same characters as the experiment with the wax candles; and he mentions, that he performed many others with similar results. Upon the whole, he concludes that "the results of them, so far from affording means for ascertaining the resistance of the air to light, do not even indicate any resistance at all; on the contary, it might almost be inferred from some of them, that the intensity of light emitted by a luminous body in air, is in a less ratio than that of the squares of the distances; but as such a conclusion would involve an evident absurdity, namely, that light moving in air, its absolute quantity, instead of being diminished, actually goes on to increase, that conclusion can by no means be admitted." * It is very seldom that this excellent observer does not come to a more happy conclusion

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* Philosophical Papers, vol. i. p. 295.

from his experiments. We see, then, that a cold flame must be most highly luminous, supposing the lumeniferous excitement which it propagates equal to that of a hot one, and this enables us partly to explain the difference in the illuminating powers of hydrogenous and carbonaceous substances. Hydrogen has a particle, whose heat is far greater than carbon, and, during the percussion of its union with oxygen, far more heat is evolved. Experiment shows, that a hydrogenous combustion will heat to the same degree more than three times as much of any body as a carbonaceous combustion. Sir H. Davy found that a volume of olefiant gas (which we shall afterwards find to consist of two particles of carbon and one of hydrogen) gave out, during combustion, 207° of heat, while an equal volume of hydrogen gave out 238°; though the former gas contains twice as many particles as an equal volume of the latter, and heats, by union, six volumes of oxygen, while the latter heats only one. Hence, *partly*, ordinary flames are bright, in proportion to the quantity of carbon which they contain, or in proportion to their coldness; and flames burn the brightest when the surrounding radiant medium which constitutes their rays is cold. The same view enables us to explain the clearness of moonlight when the weather is cold, the greater distinctness of very distant objects in chilly weather, when the atmosphere is pure, and the greater fitness of certain strata of air than certain other strata, for conveying light, which gives rise, when combined with the resulting refractions, to the singular phenomena of the mirage.

The view lately advanced of the mutual relations of heat and light, in which the law of compensation is beautifully exemplified, (the light generating heat till the heat operates so as to diminish the light, and, consequently, the calorific action depending upon it,) has some interesting bearing upon the heat of the sunbeam, in different regions of the planetary orbits. For it will be proportional to the intensity of the lumeniferous excitement there, which we have already endeavoured to shew is expressed by the same formula as their gravitation to the sun. Instead of a starry coldness, then, the superior planets may have as genial sunbeams as the earth. We found that the views advanced in this work, respecting the sun's illuminating power at the different planets were borne out by observation as fully as could be. Of their temperature we can acquire no knowledge by observation, or otherwise than by reasoning.

We see, also, that light, in passing the edge of a hot body, must have its colours changed, so that a fringe, with the weakest tint next the edge, must appear on a screen placed to receive it. For the great heat contiguous to the edge, will be apt either to produce darkness, or to develope violet light, and so on till a complete spectrum is evolved. This interference, occasioned by the motion of the radiant particles contiguous to the edge of the opaque body, appears to be a principal cause concerned in the production of those coloured fringes seen in diffracted light. The degree of heat, produced on the projecting atoms of the edge of a body intersecting a sunbeam, must be very violent. In fact, flint fuses in Villet's focus, not because a greater heat is applied to any one point, but because a much greater number of points are heated to the degree which is in every sunbeam. The intensity is the same, but the quantity is different. Around the very edge of a thin body, then, on which a ray of the sun is incident, there must be a very powerful heat, which can scarcely be conducted away by any substance, however dense, so fast as it is excited.

The limit will be immediately attained when those particles, on which the ray is incident, have attained the heat which results from the percussion of a radiant atom transmitting light; nor will we regard a second of time as too short for this, when we consider, that the atoms incident give so many millions of strokes in that time. Around this edge, then, there will be a little cylinder of radiant matter very unfit for continuing the rays of light which pass most contiguous to the edge, and it will, nearest to the edge, transmit a weak colour, as violet, and so on to red. A solar ray may also be admitted by an aperture, in which case, the phenomena will possess a more definite character, in consequence of the thermo-lumeniferous axis being symmetrical. When a linear aperture is used, the heat will be propagated from both sides, and the central ray will probably be in that state which naturally arises out of the transmission of a solar ray at that distance from its calorific base. If, again, the aperture be circular, the same thing will hold; but the attainment of the cold point will be in this case more difficult, and probably not in the plane of the perforated lamina, but behind it. The lumeniferous rays, then, in being constituted in these apertures, must have not only a motion in the course of the ray, necessary and proper to the propagation of light in that direction, but a transverse motion radiating from the centre of the aperture, or from the axis of the ray, which will require that the light, in being transmitted, shall be modified, so as to produce colours symmetrically related to each other. The smaller the aperture, the more intense the transverse excitement of the ray. By admitting sunbeams thus, through small slits and apertures, and by the use of dense atomic bodies, the natural symmetry of the sunbeam, and the state of its polarity, are changed together. The radiant medium, in fact, at the dense body, is as it were changed from a tessular crystallization to one possessing free polarity; consequently, when the illuminated structure is viewed with a telescope, as by Fraunhofer, or received on a white surface, (as Mr Herschell did with polarized laminæ, when detecting the lemniscoid developed by the confluence of two axes,) spectra and chromatic axes are displayed, as when other polarized media are viewed in a similar manner. The beauty of the coloured rings, spectra, and fringes, which are thus developed, surpasses that of the equatorial laminæ of other crystalline media, in the proportion that the radiant medium surpasses all others in symmetry and transparency, and fitness for the development of chromatic phenomena. Those which Fraunhofer saw, by admitting a sunbeam through four small apertures, must have been truly magnificent; and we have only to inspect the form which was developed, by admitting beams through four small apertures placed in the angles of a square, to see more of the structure of the radiant medium than could have been expected in an accidental experiment. Drs Brewster and Seebeck have shewn how sensitive the polarization of a mass destitute of molecular individuality, such as a bit of glass, is to changes of temperature; and a thermometer has even been suggested founded on this principle. But I hasten to attempt the structure of a variety of chemical and natural bodies, according to the principles that have already been laid down, and, after the perusal of the following pages, the preceding may, perhaps, be found more interesting.

BOOK III.

OF

NATURAL AND CHEMICAL SUBSTANCES.

ON ATOMS, PARTICLES, AND MOLECULES.

The Radiant Medium, from its universal diffusion, from the minuteness, the solidity, the pungency, and other features of its atoms, gives rise to phenomena in the economy of nature, not a little different from those of other aëriform media. These phenomena, however, are only its natural and specific properties, depending on its physical constitution, and all other bodies possess analogous properties, in as far as their physical constitutions are analogous. It has been treated of apart from other chemical bodies, not because it is essentially different from them, but because it is the element to which they are related in such a manner, that their particles are symmetrical structures constituted of radiant atoms.

These particles, commonly called the Atoms of Bodies, possess, as is always received in chemistry, the same form, magnitude, and structure, in the same species of substance. But in dissimilar bodies they differ in these particulars, and this constitutes the specific difference between one body and another; the solid impenetrable matter of which they consist being at the zero of heat, or in a state of rest, universally the same in nature and properties. But as two bodies may be in very different states of calorific excitement, while their temperature, that is, their disposition to part with their heat, so as to warm or affect by heat a third body, may be the same, specific heat must be regarded as an element modifying the condition of the ultimate atoms of bodies. In acquiring a certain specific heat, then, when it enters into the composition of any specific body, the substance of an atom of common matter acquires a specific modification, and this necessarily affects it in all those qualities by which only it can be known to us. But in a state of absolute coldness, or when the calorific excitement of any number of bodies is every way the same, the impenetrable matter of which they consist is the same in nature and properties universally.

This doctrine, though little attended to by many chemists, has generally found advocates in those great philosophers, whose general knowledge of physics enables them to form expansive views of the structure of the universe. The reason why it is but little entertained by some chemists is, because they think that, if all undecomposed substances really consisted of the same kind of matter, doubtless they ought to be able, in some experiment or other, to reduce them to the same. But this is to entertain far too high a conceit of chemical power. It requires the highest energy of analysis to separate oxygen from silicon, though each of these substances possesses a highly symmetrical form and specific individuality of its own, and they be merely retained in union by a well-balanced chemical affinity. Until the vigour of our decomposing apparatus be greatly encreased, there is no reason to suppose that, though dissimilar masses were constituted of radiant matter, or the matter of light, they ought to have returned to this state during the manipulations of the chemist. In many experiments, a few millions, perhaps, of the external particles over which the voltaic repulsion or other destructive energy is diffused, are dissipated into atoms, as, doubtless, in others, such as sulphur, phosphorus, and carbon, they are resolved into hydrogen. But how many millions must be destroyed before a loss of weight would be indicated? Even though the surface of the mass exposed for decomposition were half a square inch, and the weight of a particle as great as that of gold, which is believed to be more than 100 times as heavy as one of hydrogen, it is certain that a complete stratum of the superficial particles might be dissipated, without diminishing the weight of the remainder $\frac{1}{1000}$th of a grain; for a single grain of gold may, even mechanically, be made to cover completely 600 cubic inches.

If we could operate with our voltaic and oxy-hydrogen foci upon a few particles of a substance, perhaps even with our present apparatus we might be able to resolve any body into radiant matter. But we must operate upon sensible masses, whose quantity constantly exercises a powerful energy to reproduce the substance as fast as it is destroyed, and whose dissipation, though a particle were destroyed every second, would require the experiment to be sustained for many ages.

The convertibility of one undecompounded substance into another is, however, everywhere apparent, by the aid of those instruments of analysis which constitute the organization of plants and animals, and, not unfrequently, even by the aid of the more rude apparatus of the laboratory. Thus, it appears that more carbon is ejected from the lungs than can possibly be absorbed from the food consumed, though some be also added to the system. Herbivorous quadrupeds, which are not known to consume any phosphorus or nitrogen, generate it out of grass or water in many ounces every day. During the hatching of eggs earthy matter is developed. Plants, fed upon pure water, supply themselves with carbon, oxygen, hydrogen, potassium, silicon, iron, &c. &c.; the introduction of which, from without, in such quantities as are found in their substance, has, in many experiments, been rendered impossible. All the phenomena of assimilation are easily accounted for, on the supposition that the unchangeable element of matter is more minute than any of our chemical substances, and by such a supposition, a reason is at the same time given why the assimilating apparatus, which has such an office to perform, is of a structure so perfect and so complicated. But, on the hypothesis that plants and animals receive from without all the undecompounded substances which enter into the composition of their bodies, we must provide food for them for which they have no appetite, and discover it where it is not known to exist. To resolve all bodies into hydrogen and atoms, will, probably, be the highest effort of chemical energy; and it may be long before this effect be produced, except, perhaps, with a few, such as phosphorus, sulphur, oxygen, nitrogen, sodium, and other unexpanded forms, which may perhaps be resolved into smaller bodies; for they contain faces of atoms pressed against each other, and are, consequently, subjected to a repulsion operating to expand them.

But though some chemists pay but little regard to the ultimate constitution of matter, and are not excessively curious as to the *natural* affinities of chemical bodies, others are disposed to press these views to the utmost limits of which the evidence will admit. Of this number is Thomson, a most learned and acute chemist, from whom I shall often have occasion to differ, but never without admiration of what he has achieved. Speaking of this subject, he says, "With respect to the notion entertained by Boscovich, that the ultimate atoms of bodies are homogeneous, we are incapable, at present, of deciding whether it be well or ill-founded. It is not likely that any of these ultimate elements of bodies has ever come under our inspection. All our simple bodies are, most probably, compounds. It is possible that the ultimate elements of bodies may be very few,—it is even conceivable that they may be reduced to two,"* &c.

But if little has been done by the manipulations of chemistry to prove the ultimate unity of matter, far less has been done to disprove it; and, by the evolution of the combining ratios of chemical bodies, we are now in a condition for inquiring into the ultimate structure of these particles. Neither could any time be anticipated as more favourable for such an investigation than the present, since it is not to be concealed that chemical analyses begin already to be sophisticated, with a view to conform them to certain atomic weights, which cannot be expected to be absolutely correct, when their very basis lies in the weight of gaseous bodies, a circumstance in their constitution so variable, that no two specimens of a gas in the hands of different experimentalists were ever found to possess the same weight. Even vital air itself gives such variable results, that the unobjectionable experiments of Saussure, compared with those of Berzelius and Dulong, indicate a difference of more than three grains upon a hundred; and the weight of hydrogen fixed upon by Dalton, as the basis of his system, differs from that now generally received, by about fourteen grains in a hundred. It is not to be denied, that, in determining the weight of a gas, it is always necessary to take the mean of experiments often differing by a large fraction of the whole, and this is at once to recognise error as unavoidable, and to do sacrifice to it.

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* First Principles, vol. i. p. 31.

Most ingenious attempts, indeed, have been made to avoid the sources of error which are obvious in weighing bodies as light as air, by ascertaining the weight of their matter in another state; and, in most cases, it appears that, in this way, accurate indications of the quantity of gaseous matter in a given volume, that has been generated, might be determined. But where water is resolved into free or gaseous hydrogen, and oxygen remaining in a state of union, it will afterwards be shewn that there is a cause operating that requires a correction on the indications of the balance, before their relative quantities of matter be accurately assigned. This state of things has introduced a small difference between the greater number of the atomic weights advanced in this work and those generally received; but by applying an uniform correction, it will be found that they are, in general, nearly the same, or some multiple of each other. It is to rigid analysis, however, that an appeal is chiefly made for the truth of the atomic weights here advanced.

The particles of bodies, where they are highly symmetrical, and when their electrical fluid is well-balanced between their pyramidal and prismatic regions, generally exist singly, at least when they aggregate, or unite with other bodies nearly of their own size. But when their symmetry or electrical equilibrium may be improved by so doing, or when they unite with particles larger than themselves, as has been stated in a former page, they are apt to group together into compound particles, or molecules, consisting of a definite number of particles. These molecules often possess very singular forms. In the atomic structure of matter, we observe the same beauty and variety which are everywhere obvious in its sensible forms. The particles of bodies are neither all cubes, nor spheres, nor spheroids, but as various in their forms as the species of natural substances themselves. The limits, however, towards which the polarized forces constantly operate, as has been stated in a former page, is the development of some form symmetrical on opposite sides of the equator, very highly polygonal, and tending to be spherical, its faces being invariably equilateral triangles, or lozenges, of 60° and 120°. The radiant medium, then, may be described as a medium existing in every place of the universe, from which it is not excluded by more dense bodies, and composed of disunited *atoms* of matter symmetrically related to each other, and acting upon each other according to the common laws of physics. These atoms of matter variously grouped, chiefly in consequence of their electrical relationship, and retained in cohesion by their attractions, constitute the *particles* of sensible bodies, and the number of atoms involved in a particle denotes its *atomic weight* at the zero of heat. These particles, associated into little masses, more fit for entering into chemical or crystalline union than the individual particles themselves, constitute the *molecules* of these bodies; and, according to the number of particles which enters into them, they may be called binate, ternate, quaternate, quinate, senate, denate, or duo-denate molecules.

I shall endeavour to sustain these views, by shewing that the particles which we would naturally construct out of atoms, according to the laws of physics contained in the First Book, as most suitable to certain regions of nature, and most likely to be developed there out of radiant atoms, do, in reality, fulfil the chemical relations of all the most interesting substances met with in nature in such places; and that while new changes of properties are very obviously connected with changes in form and structure, the change in the weight of their combining proportions is an accurate measure of the accession or loss of atoms which they have undergone. The atom is, of course, fixed upon as the unit of atomic weight; and it is a coincidence, as happy as it is curious, that this leads to nearly the same series of atomic weights as that fixed upon by Wollaston, which makes oxygen 10.

HYDROGEN.

Of all known bodies we naturally expect to find that hydrogen gas possesses the most simple structure. It is nearly fifteen times lighter than common air. Like the radiant medium itself, it is invisible, and possesses no action on the eyes, nose, tongue, or lungs. It might, perhaps, even replace the radiant medium in the atmosphere, without our discovering for some time (combustion excluded), in what way the world had been changed. Darkness, oppression, and death, would, no doubt, follow, because light is essential to life; but of all bodies that could be mingled in the atmosphere, hydrogen, in particles, (or senate molecules), would be by far the most innocent. Every circumstance induces the belief, that it is more immediately connected with the radiant medium than any other body.

Now, of all the combinations of the atoms of matter, none is so immediately obvious as that produced by two atoms applied base to base. This is a particle of hydrogen gas, (Fig. 3.); its atomic weight is two; its form, a triangular bipyramid terminal edge, 70° 31′ 44″; equatorial edge, 141° 3′ 28″; inclination of an edge to an axis, 35° 15′ 52″; inclination of an edge to a perpendicular let fall from an extremity on the opposite edge, 54° 44′ 8″; plane angles, 60°; length of an edge, 1°; length of an axis, 1.62348 + (= 2 cosine 35° 15′ 52″).

The form of hydrogen is wholly pyramidal. It is, consequently, highly electro-positive, and, accordingly, where it is free to move, it must seek an electro-negative medium in which it may exist; and, therefore, in the voltaic focus, it must be developed at the negative pole. It has, therefore, also a possibility of entering into chemical union with all bodies which are electro-negative in relation to it. These results are amply confirmed by experiment.

Of all bodies, it is the most fit for sustaining a high degree of specific heat, or atomic tremor, for its two poles are at the extremities of a solid axis, and are very pungent and vibratory; and being directly opposite, can react upon each other in the most perfect manner, and sustain most symmetrical vibrations. Many attempts have been made to ascertain the specific heat of hydrogen gas, and they all agree in assigning to it a heat far greater than that of any other body.

Now, this comparatively great heat which it possesses, when at the same temperature as other bodies, doubtless diminishes the energy of its attractive fluid more than their smaller degree of heat diminishes theirs. In consequence of this, its attraction towards its own particles and the earth, must be considerably less than theirs, when their temperatures are the same; and, therefore, to find the true specific gravity of hydrogen, it is necessary to depress its temperature beneath that of other bodies, until the action of its specific heat, in diminishing its attractive or gravitating energy, becomes equal to that of the bodies with which it is compared. At the same temperature, then, a volume of hydrogen, supposing no ponderable body but itself in the vessel weighed, is lighter, in proportion to its quantity of matter, than common air; and the deviation from the true ratio, is still greater when it is compared with vital air, which, when the gases are arranged according to their specific heats, is found almost at the opposite extremity of the table.

But the attempt to ascertain the true weight of the matter of any gas, by weighing a volume of it, seems, in the present state of our knowledge, to be rather a hopeless experiment; and, in the case of hydrogen, more than in any other instance, the attempt must lead to error. In any instance whatever, a true indication can be obtained by the balance, only when the density of the included radiant medium is equal to that mingled with the atmosphere without. For every volume of a gas is, in reality, a mixed atmosphere of the gas considered, and the radiant medium, or common vapour of matter, which ascends into every region till it constitutes an atmosphere of its proper density. Now this degree of density is different, according as the gas makes a nearer approach to the radiant medium itself. For, in this ratio, other things being equal, the gas repels the radiant medium more, or acts in excluding it, or in preventing it from rising. The only index which we can obtain of this exclusive action upon light possessed by different gases, is their refractive power, which seems to indicate the imperfection of the radiant tissue included along them, arising from their power of repelling light. In virtue of this, the rays are less under the constraint of the original directive force, and the refraction is, consequently, greater. The actual amount of refraction produced by a volume of hydrogen gas is very small, which would induce the belief, that the radiant medium was more dense within than without, and that, in as far as the radiant medium is concerned, hydrogen ought to weigh too much. But this may arise simply from the inflammable particles being determined into the very lines demanded by the incident light, to preserve a continuity of their direction. For, of all known bodies, except the metals, which, as we shall afterwards find, may be regarded as covered over by a surface of radiant matter, often of light itself, hydrogen possesses the greatest atomic refractive power. It is therefore very difficult to satisfy one's-self as to the density of the radiant medium included along with a volume of hydrogen. There can be no doubt, however, as to the density of its own particles, (by which expression is always meant, in this work, the number of particles in a given volume,) for every phenomenon points to the fact, that, when the temperature and pressure are the same, hydrogen contains, in the same volume, the same number of particles as most other gases.

But though the true weight of hydrogen cannot be ascertained by the direct use of the balance, it might seem that it might be ascertained without the interference of the radiant medium, by disengaging a certain volume from a mass of matter of a known weight, and noting the weight lost, corresponding to the development of a given volume of hydrogen disengaged from it. By making use of some of the compounds of carbon and hydrogen, perhaps a nearly accurate result might be obtained in this way; and if so, it would be palpably seen, (what is indeed already obvious from various experiments in organic analysis,) that a great loss of weight is sustained, when solid hydrogen, in a state of combination in which the tremor of its poles or its specific heat is prevented, is changed into the gaseous state.

The very ingenious methods resorted to by Thomson, and Berzelius and Dulong, in which these philosophers had recourse to the analysis and synthesis of water, necessarily involve an error of the same amount, according to both methods. In consequence of the very small heat of fixed oxygen, compared with liquid water, the same number of atoms in the state of oxygen must weigh more than in the state of water. Hence, when a quantity of water is weighed, then decomposed into oxygen and hydrogen,—the latter being permitted to escape, the former being detained and weighed along with the residuary water,—the loss of weight, indicated by the balance, is too small; for the matter has gained weight or attractive energy, in assuming the form of oxygen. In like manner, when a certain weight of oxygen is, by the aid of hydrogen, converted into water, and the weight of the hydrogen thus occupied is inferred to be just equal to the difference between the weight of the oxygen abstracted, and that of the water developed, an error to the same amount is incurred. It will presently be shewn, that, though oxygen be the form which must constantly, and almost exclusively, result from the destruction of water in the hands of the chemist, yet there is no oxygen in water; and that it partakes almost wholly of the nature of hydrogen, in being lighter in the liquid, and still more in the aëriform state, in relation to its quantity of matter, than other bodies. It is rather annoying, that the only instances where this source of error, arising from great differences in specific heat, exists to any considerable amount, should be those of oxygen and hydrogen, on which the atomic weights of chemical works are, in a great measure, reared. The difference, however, is not very great, for, according to the absolute atomic weights here advanced, the specific gravity of hydrogen gas, deduced from its atomic weight, compared with that of common air, ought to be near .098; Biot and Arago having found it .0732; Thomson, .0694; Berzelius and Dulong, .0688. The more exquisitely the experiment is performed, the greater the error that is incurred, for its exclusive action on the radiant medium, and its specific heat, will increase with its purity. According to the views here advanced, 100 cubic inches of hydrogen, were they in the same circumstances as to specific heat as oxygen, ought to weigh about three grains, while the most accurate experiments assign from 2.24 to 2.118 grains.

How great the number of particles of hydrogen may be, even in a cubic inch, we can form no idea. It does not appear that apertures can be formed, through which even water cannot pass. Hydrogen may evidently be transmitted through any pore which can transmit radiant matter, for the equator of hydrogen is merely a face of an atom of radiant matter. But, for its transmission through such small apertures, it is necessary that the body containing the aperture shall be a dissimilar substance. If it be of a nature nearly similar to that of hydrogen, its repulsive fluid, covering the pore, will be recognized by the hydrogen, which will be kept from contact. Were it not that organic membranes, and tissues of all sorts, are, in a great measure, composed of hydrogen, perhaps some substance might be found that would transmit hydrogen and detain other gases, which is a great desideratum in chemistry. Hydrogen passes through small apertures with far greater velocity than other gases, and, at the same time, more silently, the whistling sound produced by air rushing into a vacuum, or from a state of compression, being greater as the magnitude of the particles transmitted is greater.

The simple structure of hydrogen leads us to expect, that, in some form or other, it should be a most abundant production of nature, especially in regions contiguous to the radiant medium. For its development, indeed, nothing more seems necessary, than that two contiguous atoms of radiant matter, whose symmetrical relationship is suspended, should be in consecutive electrical states, and in an electro-negative medium, or one disposed to restore its equilibrium by the evolution of electro-positive bodies.

Whether the bipyramidal form thus developed, would naturally possess only a momentary existence, or might be more permanent, would probably depend upon the temperature, the intensity of the consecutive excitements, and those circumstances generally, which favour a nearer approach of the angles of the atoms, and a more perfect displacement of the repulsive fluid lodged on the two faces, whose natural aversion to union, and recoil when the same electrical state is induced by proximity, or both, must be overcome. But, at all events, it is reasonable to believe, that, if hydrogen were developed in such a region, it might be fixed by being made to enter into union, and thus its existence might be detected.

Now, a physical state of things, possessing the very characters required, exists in the violet confines of the solar spectrum. It has been shewn in a former page, that this region is electro-negative, and the successive atoms of the radiant matter there, whether in such a state of excitement as to produce vision or not, are in consecutive states, while the stratum of the dense substance, which is to receive the hydrogen, necessarily destroys the symmetry of the contiguous atoms, and permits an union. In these circumstances, then, it seems very probable that hydrogen should be developed. Now, so eminently do these phenomena take place in this region of the prismatic spectrum, that it has already been named hydrogenating. The subtile body has been made to unite with various substances possessing an affinity for it; more especially with the chloride of silver, which immediately indicates the incidence of hydrogen, by changing from white to black.

In the natural sunbeam, a similar apparatus exists, though of weaker energy; and, therefore, we cannot deny that a great quantity of hydrogen may be every day generated by the sunbeams. That hydrogen should not be found in the atmosphere in a gaseous state, even though generated, is only what is to be expected, for, as will be immediately shewn, the gaseous is not the natural condition of hydrogen. Neither does it follow, that hydrogen thus generated should be a permanent body. To assert that it is so, in any case indeed, it is necessary to suppose that the repulsive fluid is completely excluded from between the faces which are pressed together; or that such an adhesion takes place as is adequate to sustain a form which is not in a state of natural equilibrium. Amongst electro-negative bodies, hydrogen thus generated, may, perhaps, exist for an indefinite time; but if insulated, and exposed to the re-action of its electric state, which is strongly positive, it is difficult to see what could prevent it from opening up. It is more reasonable to suppose, that, though at the time when the particle was generated, the repulsive energy proper to two faces was so far overcome that the two atoms of matter cohered by their three equatorial angles, and were for a longer or shorter time retained parallel to each other, with a force which the repulsion, in the direction of the axis, could not overcome, yet that such a particle is not quiescent, and, in the fire of a sunbeam, is either aggregated with others into molecules, whose electrical state is quiescent, or opened up, so that the two atoms shall remain adhering by the two angles, or one edge, as by a hinge. The substance thus generated is not an individual body, but two of them, when united, constitute a hollow particle, whose form is that of radiant matter itself, with a pyramid on each face, and whose function in the economy of the universe, as will be afterwards illustrated, is second in importance to the radiant medium only.

Hydrogen, then, may be regarded as an active and intermediate form, resulting from light more immediately than any other substance. It is a binate molecule of radiant matter, with three angles instead of two cohering. It may be permanent for a great length of time, if kept cold, and relieved by aggregation or union, from its strongly electro-positive state. But, if recently generated, and left without pressure or union, it probably opens up in the course of time, and gives rise to another substance, to be treated of afterwards. Whether the hydrogen procured from the decomposition of water, could be in any measure destroyed, we have scarcely the means of discovering from the experiments which have been made. Its destruction could only be indicated by a diminution of volume, for when it mingled as radiant matter with the radiant medium existing along with it, the chemist has done with it.

The term Hydrogen is applied in chemistry only to a gas or body which, when disunited from the other bodies, is conceived to be capable of existing at all known temperatures only in the aëriform state. It is evident, however, that its particles may group so as to constitute a molecule, whose electrical state shall be in the condition of a much more perfect equilibrium than that of a single particle. When once elevated into the gaseous state, it does not appear, indeed, that it can be easily made to abandon it. Its extreme specific heat must produce a repulsion on every contact, except, perhaps, when the number requisite to constitute a molecule comes on at once in their proper positions. In these circumstances the disposition to symmetry and electrical equilibrium might be expected to overcome the mechanical rejection from union, arising from a vibratory movement on all the angles, and the extensive sphere of repulsive fluid surrounding each particle.

When six particles of hydrogen unite by their equators, there results a senate molecule of most admirable symmetry and èlectrical constitution, (Fig. 33). Each of its six parts has a solid axis, and is electro-positive, while the whole, considered as a single form, has no axis at all, and is very highly electro-negative. This senate molecule of hydrogen is a particle of water. That water consists entirely of hydrogen, may be shewn by decomposing it in a very highly electro-negative medium, adverse to the development of an electro-negative form. In other circumstances, where it is not restrained by such an arrangement, as soon as one particle of hydrogen is drawn out of the circle of six, the remaining five, by the proximity to the electro-positive part, tend to assume an electro-positive form. Now, this they may do by a simple movement; and thus the senate molecule of hydrogen, so singularly fitted for accommodating both the positive and negative electricities when decomposed, parts them between two forms, one highly electro-positive, the other highly electro-negative. In other cases, as will be afterwards shewn, other forms besides must result from the decomposition of an atom of water. But it is not to be denied, that, by decomposing water at a negative voltaic pole, the positive being removed to a distance, and the effects of induction as much as possible prevented, this liquid is wholly resolved into hydrogen. No other substance is either given out or absorbed; and, to conceive that particles are transferred through the connecting body to the positive pole, as, for instance, through the living body of man, without occasioning inconvenience, is more extravagant than the case demands. Whether hydrogen is ever resolved into water during chemical experiments, is well worthy of inquiry. Water is always found in hydrogen gas, even after transmission through dry chloride of calcium. Its development might certainly be expected, when hydrogen is nascent in great quantities. When escaping through the pores of a bladder, perhaps a part of it emerges from the exterior side, as aqueous vapour; and if as much hydrogen as possible were condensed in charcoal, perhaps a part of it might be extracted as water, especially if a little water were introduced into the charcoal along with the hydrogen, to determine to the evolution of more. The admirable Boerhaave concludes, that water is a permanent body, because a quantity, hermetically sealed up in a bolthead by Clavius the mathematician, remained without contracting in volume, or otherwise changing, for eighty years, during which it hung in Kircher's laboratory. It were much to be wished that modern chemists would imitate the older ones, in performing their experiments on a scale sufficiently ample. It would be very interesting to know what would become of a volume of hydrogen, cooled and compressed as much as possible, and exposed to the sunbeam, or kept in the dark, for as many days as the water was years. It is not to be forgotten, however, that 100 cubic inches could only produce one globule of water $\frac{8}{1000}$th of an inch in bulk.

WATER

Is a senate molecule of hydrogen; its atomic weight is 12; its form is that of a frustular bipyramidal dodecahedron, concave on both poles, and without a solid axis, (Fig. 33). The equator is a regular hexagon, and though the matter in the centre, and on six equidistant radii, have no sensible thickness, the equator is everywhere impervious.

Water, when entering into union with bodies constituted of larger molecules, which, from their unconformable shapes, cannot dispose of it in the proper quantity that they demand in individual particles, often aggregates into ternate molecules, whose atomic weight is consequently 36. Next to this there is the septenate molecule, which consists of a particle in the centre, with six around it, one on each of its edges. But that which performs the most important part in the economy of nature, is the senate molecule (Fig. 34), which results from the approach of six, and contains in the centre a hexagonal pore. Such a molecule must possess great permanency, for the subtile matter is very perfectly circulated; and there is no diameter, along which a repulsion, tending to break up the molecule, can be instituted. When fastened together by other bodies, a double molecule, in which one particle is above another, the poles not being in contact, also frequently occurs. The form of the aqueous particle enables us to anticipate those numbers which must prevail in its combinations, and the characters of the forms which will most readily combine with it. Those bodies only which have a positive axis, terminated by a trihedral angle, can find access to its poles; and the numbers in which they may be combined are one, when their particles are large compared with a particle of water, and two when they are small. Any body may unite around the equator; and those having parasitic forms, or re-entrant equatorial angles, such as Figs. 6 and 7, conformable to the equatorial edge of a particle of hydrogen, will be retained with the greatest force, being held in cohesion by four angles. The number in which such bodies must unite is three. The number six is possible, in as far as the form is concerned, but such a number of any other body may be expected to overcharge a single particle of water; and we may generally expect to find in hydrous molecules, that three particles of the peculiar substance are arranged around the equator of a particle of water, one on each alternate segment. The most symmetrical mode of arrangement is when one particle of the body demands one of water, and the six then group, so that in the centre is a senate molecule of water, and six particles of the hydrated substance around.

A single particle of water is, doubtless, very much too small for being seen, so that we cannot obtain sensible evidence that it possesses the form which is here assigned to it. But the evidence on this subject which is afforded in nature, is almost as convincing as the actual vision of a single particle. The particles of water do not, like hydrogen, inveterately affect the aëriform state; but, on a sufficient reduction of temperature, aggregate into visible masses, and these masses, when, by being precipitated from solution, they possess crystalline individuality, are most perfect reproductions of all the prominent features of the aqueous particle. Water always exists diffused through the atmosphere, and its existence there, in single particles, is compatible only with a certain temperature, pressure and electrical state. When that state does not exist, and the temperature is too high to admit of the institution of solidity, it aggregates in little masses, which, when they are slowly formed, are probably little hollow balloons, constituted by aqueous particles, their axes directed to the centre. This is the only symmetrical form possessing individuality, which can result from particles of water restrained from contact, and it may be regarded as a molecule of vesicular vapour, or of dew; but when the heat of the particles is less, so as to admit of a crystalline arrangement, very interesting phenomena must occur. The first movement of the aqueous particles must be into ternate molecules, and then into septenate, whose symmetry is as great as need be sought for; they are isomorphous with the senate, Fig. 34, the central pore being occupied with a particle of water. These we may regard as the molecules which unite and develope crystalline forms; or it may be, that a septenate molecule becomes the nucleus, around which individual particles, or ternate molecules, are arranged. It matters not in which way it is generated; there must constantly result, upon any supposition, a form consisting of a central part, from which six radii emanate at angles of 60°. These radii may again have secondary branches, emanating at a similar angle, or even the primitive form may be reproduced, by the hexagon being completely filled up. The various forms which may be produced seems almost infinite, but those which can most easily be constructed, are the very forms of snow flakes, and no others. In the plates to the recent voyages to the Arctic Regions, most perfect illustration of these views will be found. The subject was long ago examined by Descartes,* who noticed many having twelve radii, or six principal ones, with their intervals bisected by inferior ones, as may be easily conceived. He also observed two flakes of snow united by a prism, as by an axle, as has been since remarked Six-sided spiculae, or prisms, which are described by Hooke as hollow, also arise very naturally, when a hexagonal base is afforded. Hence, they are frequently met with in glacial hoar frost attached to icy surfaces, as they are sometimes in the air attached to flakes of snow. Fig. 35 represents forms of snow-flakes copied from the Rev. Mr Scoresby's first work on the Arctic Regions. But any others of those given in his four plates are equally illustrative, and this is true also of those figured in other works. Such are the most beautiful forms which arise out of aqueous particles, when they are permitted to arrange themselves in contact according to the laws of their symmetry. When the temperature is raised they dissolve, and the mass becomes water. In this state the symmetry is not less, for there can be no doubt that they are arranged in laminæ, their equators in the same plane, the contiguous particles, and the intervals between the laminæ, being more or less distant, according as the degree of heat is greater or less. The heat of the equatorial region being much less than that of the polar, the equatorial attraction is stronger, and the calorific repercussion in the plane of the equator, is less than that in the direction of the axis. Hence the intervals between the contiguous particles in a lamina are not so great as the intervals between the laminæ; and it would be very interesting could we ascertain, in terms of the diameter of the particles, how great these intervals are, corresponding to given temperatures.

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* Princip. Meteor. p. 194.

Although the aqueous particles be so light, their specific heat so great, and they seem every way well adapted for the aëriform state, yet, so quiescent and perfect is the symmetry of their constitution, when aggregated as water, that, under the atmospherical pressure, they cannot be dissipated rapidly as steam, till they be heated to 100 cent., or 212° Fahr., at which, in ordinary circumstances, water boils. But when the quantity is small, and irregularly diffused over the surface on which it lies, so that its symmetry is imperfect, water evaporates much more rapidly. Its ebullition is also greatly facilitated by the introduction into the vessel (especially if it have a smooth surface), of some irregular body, which may break in upon the symmetry of the aqueous structure.

There is no other position in which the aqueous particles possess so great symmetry as that which constitutes snow and water. In this body the truly crystalline state, or that in which the particles are united by terminal edges, a pole of one being applied to an equator of others, can only develope an imperfect form. The circumstances in which water shall possess a maximum density, must be when, by a diminution of heat, the intervals in and between the laminæ have disappeared. But such an arrangement as this would imply a degree of cold probably below that at which alcohol would freeze, while at 0° cent. or 32° Fahr., water becomes solid. If a volume of water could be kept, during congelation, in a state of perfect quiescence, and the cold applied in lines parallel to the laminæ, perhaps the successive laminæ could be hardened and condensed upon each other, and some approach effected towards the substance alluded to. But in nature, and all practical experiments, other phenomena take place. When water is cooled down to about 3° cent., or 39° Fahr., its particles acquire a disposition for the crystalline or terminal arrangement, which the force of symmetry cannot prevent; for symmetrical individuals, like flakes of snow, cannot be developed in a mass of water. This tendency affects the symmetry of the liquid, renders it unfit for being circulated through the vegetable structure, and produces a notable expansion in volume, which increases till the whole mass becomes solid. The degree of hardness which the mass ultimately acquires is very great, and there results a glacial body, seemingly destitute of cleavage planes. But if the cold has been applied at the surface, it seems to follow that the mass must consist of rhomboids, more or less fully developed, and interlaced with each other, having their axes perpendicular to the surface. Any particle in the superficial lamina, on which a ray of the greatest cold (or the coldest ray of heat, which is the same thing), is incident, or which is any how cooled more than the others, will become the apex of a rhomboidal axis. For three subjacent particles will be fixed on the equidistant terminal edges of the first, and to these others will be added in the same line, thus determining, more or less perfectly, the three terminal edges of a rhomboid. No cleavage of a hard mass of ice has been obtained; but it is the general opinion of philosophers, that the rhomboid is the primitive form of ice. Dr Clark has, indeed, found ice in rhomboids; and the optical observations of Dr Brewster prove, that the axis of the crystal (which must either belong to the rhomboidal or pyramidal system), is perpendicular to the surface of stagnant water. When a lamina of water, as thin as possible, is extended on a plate of cold glass, and examined under the microscope, some very interesting phenomena are observed. The forms which result are pinnated fronds, so very similar to those of some algæ, such as the acute-angled varieties of the Ptilota plumosa, that a figure of one would serve also for the other. The angles are all exactly 60°, or its supplement; and it is curious to remark, that, as the summit, either of the principal or a subordinate branch, stretches along during the progression of the congealed part, the angle formed by the summit of the axis of the branch, and the summits of the lateral axes, simultaneously developed, is always 60°. When water evaporates from a surface very equally heated, the portions which remain the latest seem to possess similar pinnated forms.

Water is very passive in its action upon light, transmitting it unpolarized, to very considerable depths, and the different colours deeper, according to their force of penetration. Hence, the light transmitted by water, when it has ceased to be limpid, becomes yellow, and ultimately red, as has been observed during descents in diving bells. When a ray of perfect light is incident vertically, it is not sensibly refracted, but when obliquely incident it is partly reflected, partly refracted, and, at a certain angle, water is known to single, or polarize the reflected pencil of light completely. The polarizing angle will depend upon the angle which the axis of polarization forms with the axis of the form which may justly be regarded as a perpendicular to a lamina of water, or the surface of a stagnant portion of the same. To find the axis of polarization, let us produce the edges fronting the axis, and draw perpendiculars from the external faces. Thus, we shall obtain six pairs of lines on either side of the equator, of which four are always in the same plane, and which form equal angles of incidence respectively with the axis, or perpendicular to the surface lamina, or equator. These angles are 70° 31′ 44″ and 35° 15′ 52″, the resultant of which is 52° 53′ 48″. Now Malus says, "Si on fait tomber in faisceau de lumiere sur la surface d'une eau stagnante, et sous l'angle de 52° 45′, avec la vertical, la lumiere réflèchie a tous les caractères d'un des faisceaux produits par la double refraction d'un crystal." * Between these angles there is only a difference of 8′ 48″, which is quite inconsiderable, compared with those to which observation must be constantly subject; and, probably, at different temperatures, results somewhat different would be obtained.

Let A X (Fig. 36,) be the axis of a particle of water, P p P′ p′ will represent its axes of polarization inclined to the former at an angle of 52° 53′ 48″. Light incident in this direction is singled by reflection, with its edges parallel to the equatorial edges of the particle of water which lie in the plane of incidence. A particle of water, then, could we see the ethereal rays which it singles, becomes the origin of the edges of a six-sided pyramid of singled light, the edges of the ethereal molecule being perpendicular to the edges of the pyramid.

The specific heat of water is evidently very great, but it must be less than that of the hydrogen which constitutes it, for the whole equatorial region is now bound together, nearly in a state of coldness or rest. In the liquid state, its specific heat cannot be so great as in the aëriform; and it appears from experiment, what might be generally inferred from theory, that it is still less in the solid state. Many experiments have fully proved the great specific heat of steam. When only a small quantity is condensed in water, the liquid is warmed in a very remarkable manner; yet, so efficient is coal as fuel, that, for every pound of coal consumed in a furnace, about four pounds of water may be converted into steam. The difficulty of generating steam arises, however, not altogether from the additional calorific excitement which a particle in

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* Malus, Theorie, p. 222.

the liquid state must possess before it assume the aëriform; but because there is such an immense multitude of particles, even in a small volume, among which the heat must be equally distributed, and because the vibrating or hot state, is increased with difficulty, when it is already great. Bodies receive accessions of heat with increased difficulty, the hotter they are previously to exposure; or, in the technical language of chemistry, the capacity for caloric increases with the temperature. The difficulty of increasing the atomic tremor of a body, must evidently increase the nearer it is already to the limit of the vibratory action of which it is capable, so that, for equal increments of the moving force, there are not equal increments of motion generated. In the same way as water is heated slowly, it is cooled slowly; and the quantity of heat which it gives out is very great. Hence it is advantageously used for warming and sustaining an uniform temperature in hot-houses.

The fact that the specific heat of steam is greater than that of water, ought to make water, in the state of steam, lighter than the same quantity in a state of water; but we have no means of being assured that the density of the radiant medium included along with a volume of steam, is the same as that of the air; and this makes it impossible to ascertain the absolute weight of a certain quantity of water in the aëriform state. Whatever be the cause, it appears, however, that a cubic inch of water in this state is considerably lighter. Again, as the specific heat of water is greater than that of ice, though the difference be not very considerable, there ought to be a certain increase of weight, when water freezes; and such has generally been found by experiment, even when philosophers were seeking for an opposite result. It is to be remarked, that, at all temperatures, the centre of a particle of water is absolutely cold; for this is the point from which the motion is propagated which constitutes the heat of the body. It is true, that, in many other particles, the centre, for a similar reason, is at the zero of heat; but water is one of a few bodies in which this cold point is exposed to the access of other bodies. From this circumstance, it results, that a body inserted into the pole of a particle of water, cannot be easily expelled, and the hydro-molecule decomposed; for though the positive pole of the body inserted may be heated, yet that of the water continues cold, and a reverbatory percussion cannot be instituted between them. Such is the arrangement which obtains in oil of vitriol, molecular phosphoric, boracic, and arsenic acids.

Water, when viewed in small volumes, appears to be perfectly limpid and colourless. It will afterwards appear, however, that there is very good reason to ascribe the azure colour of the sky to the aqueous vapour existing in the atmosphere, and water otherwise shews its connection with the negative tints. Many salts are green only when they contain a large quantity of water; and vegetables generally lose their green colour, when the water of their composition evaporates from them. That this green colour is ultimately connected with the mechanical presence of water, may be inferred from the fact, that cellular vegetables, such as mosses, when their texture has not been destroyed by compression, however brown and discoloured they may have been for ages in a herbarium, immediately on being immersed in water acquire a tint of vivid green, as if they had been newly gathered from a wet rock.

The view of the structure of water which has now been given, leads us to regard it as the most elementary of all bodies, except the radiant medium, and this has been the general opinion of philosophers in almost every age. Such an opinion is also much more grateful to a vulgar understanding, than that water is a compound substance, consisting of two permanent gases, united by chemical affinity. Water is, of all bodies on the surface of the earth, by far the most abundant. About three fourths of the globe are covered by the ocean to an unknown depth; and about three-fourths of the bodies of animals are composed of water. The Arctic Regions, a great part of the temperate zones during the winter season, and the acclivities and summits of mountains, of a certain elevation above the sea, in every latitude, are continually covered by snow. The dry land is also traversed in every direction by rivers; and the basins of mountains, and plains, contain innumerable lakes, many of vast extent. Water also constitutes a large portion of the substance of organic bodies, both plants and animals. It is met with in the air at all times, in variable quantity, and it enters into the composition of some of the purest and hardest gems. Chemical analysis abundantly shews, that water may be present even in a very considerable quantity, without inducing liquidity even in a warm temperature. Neither single particles, nor ternate, nor senate molecules, when once constituted, are liquid, more than other hard bodies. The liquid state demands a number whose equators are in a laminar arrangement, but not touching each other; and if a molecule be confined along with other particles, which have brought its poles to rest, it is very reasonable to believe, that it will not be resolved into single particles, or assume the liquid form, till a state of heat has been induced upon the poles, amounting to that proper to water. A solid mass, having the appearance of a silicious stone, may be constituted of water solely, with little more than one-seventh part of silica, or the earth of flints, united to it.

Water, as might be expected, from the singular condition of its electrical state, is an almost universal solvent. No substance seems capable of resisting the action of water for an indefinite time, and many bodies, when mingled with it, rapidly disappear. They are said to be dissolved by it, and they are constituted in this medium much in the same way as the particles of one gas, are in a volume of another. There is, indeed, a chemical union with a certain number of aqueous particles, while there is usually none in the gases; but their states agree in the equable diffusion of the particles through the whole medium; and when the particles of a soluble body have been fully hydrated, the condition of these hydrated particles in the water is quite analogous to that of the particles of mixed gases. A volume of water, then, holding some body dissolved, consists of two parts, pure water, and the hydrated particles of the body; and by distillation, or, in some cases, by filtration, the pure water may be withdrawn, and the hydrated particles suffered to unite into their crystalline forms.

The great chemical activity of water renders it always impure. It is never obtained even from snow or ice, but chemical tests are able to detect foreign substances. When procured from electrical rain, nitric matter makes its appearance; and even when received from a gentle shower, and at a great height in the atmosphere, after exposure for a short time to the sunbeams, a green substance is developed in it, and afterwards very minute rapidly moving molecules, which have been generally regarded as animals. The purest snow on the tops of mountains frequently contains that curious organic body, named Protococcus nivalis, which excited much of the curiosity of the alchymists. That it should excite curiosity in minds inquisitive into the arcana of nature as theirs were, is not to be wondered at, when we find that it holds a place so exactly on the confines of the animal and vegetable kingdom, that the learned Professor Agardh, after describing it as a vegetable of the order Nostochinæ, says, "Globuli in animalia interdum reviviscunt.*"

When water has been repeatedly and carefully distilled, chemical tests are no longer able to detect the presence of foreign particles. We may therefore conclude, that in frequently distilled water, foreign particles do not exist in very vast numbers; yet, when we consider how many myriads must be required to give rise to sensible phenomena, we will hesitate to affirm that any considerable volume of water was ever obtained in a state of absolute purity. After it has been kept some time, substances make their appearance of a nature little looked for. Of these, ammonia is one, which we shall afterwards find to be more nearly allied in its external form to water, than any other substance.

The uses of water in the economy of nature are innumerable. Not to mention that it is the province of the waters now, as at the creation, to "bring forth abundantly" bodies whose substance is derived from water, which has been resolved into particles of other properties, the absolute utility of water as such, to creation, is incalculable. It has neither taste nor odour; and it quenches thirst; therefore, it is always grateful. It may be applied to the most painful ulcer without occasioning irritation, when nothing else can be suffered to touch it. It is beneficial to the eyes. Its action upon the human body is so refreshing, that a bath is esteemed a great luxury, and even birds do not refuse to wet their plumage, that water may find access to their skin. When deprived of the use of water, plants and animals perish; the soil loses its cohesion, and the air becomes filled with dust.

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* Systema Algarum, p. 12.

Of all the functions of water, however, none are more beautiful than those by which it at once economizes the sunbeams, and prevents injury to creation, from an excess of solar heat. It has been already stated, that more than three-fourths of the globe are covered with water to an unknown depth, and if all this mass absorbed the sunbeams like a black opaque body, both the light and heat of the dry land would be diminished. But the sunbeams incident upon the ocean, raise it into vapour, rather than warm its depths. While a sunbeam piercing an arctic sky is able to raise the surface of the ground to more than 120°, the surface of the ocean under the equator is less than 90°. Water can scarcely be warmed by a source of heat applied on its surface. Any superficial lamina, when heated, is thereby lifted up from the subjacent ones, and insulated. It thus forms an intercepting screen, through which the sunbeam cannot penetrate, for there is no radiant medium to constitute a ray beneath the surface. The superficial lamina is so far removed from the subjacent one, that it rises in steam, before those almost immediately beneath it are sensibly warmed. Almost all the sunbeams, therefore, spent upon the ocean, are occupied in raising vapour into the atmosphere. The remainder are reflected as light, and, consequently, are ready to conceive heat in any body upon which they are incident, and to increase the luminousness of the rays incident upon the dry land, and consequently their calorific energy.

The vapour which is thus raised from the ocean, performs the most admirable offices in the economy of nature. Having recently undergone a cleansing process, the oceanic vapour is pure and fresh. This is wafted by the winds into those regions whither they tend, and spontaneously presses into dry places, so as to equalize its quantity and pressure every where. It falls upon the plains as rain, where it is immediately required for the purposes of vegetation, but on the summits of the mountains it is extended as a solid mantle of snow, there to repose till the season of intense sunbeams. Such sunbeams warm the plains, and advance the vegetation, but they would necessarily parch the soil, did they not also melt the snows of the mountains. There the water cannot stagnate, and thus, when the fountains of the plains are dried, those of the glaciers are opened, and torrents pour down every ravine. These are gradually consolidated into rivers, which seek distant plains, to refresh them with dews and showers resulting from their evaporation. When the period of vegetation and solar desiccation is over, the fountains of the glaciers are again closed; then the beautiful foliage of a future season is wrapt up in its winter quarters, herbs and flowers are hid under a covering of earth, and the atmosphere displays to the philosopher and poet the grand phenomena of storm and meteor. Again the earth is, in arctic regions, where heat is most precious, covered by a mantle of snow; and, though it seems paradoxical, the fact cannot be doubted, that the effect of this cover of snow is to conserve the heat of the soil far more effectually than if it were exposed to the light. For not only is snow a very bad conductor of heat or cold, but its specific heat is so great, that the under surface of a stratum of snow reposing on the soil, is often 0° cent., or 32° Fahr., while the air at the surface is many degrees below it. At this temperature, then, which is only a few degrees below the commencement of vegetation, the covering of snow preserves the arctic soils.

But of the many beautiful phenomena to which water gives rise in the economy of inorganic nature, none is more striking than the effect of the expansion which takes place in its volume before it freezes; and what renders this more striking, is the fact, that this expansion is an exception to a law otherwise regarded as almost universal, that liquids shall contract continuously down to the point of congelation. Had water obeyed this law, in as far as the sunbeam is concerned, there can be little doubt that lakes, rivers, and the ocean itself, in frosty climates would have remained perpetually in a state of ice, with only a thin stratum of water over them during the summer months. For, if water contracted as it cooled, and became heavier continually, the congealed portions would always be found at the bottom. There congelation would commence, and be propagated upwards towards the surface, and, as has been shown, even a thin covering of water would act as an impenetrable screen to prevent the influence of the sunbeam from penetrating. Nor would the water be able to conduct heat downwards, so as to melt the ice. Upon the whole, in as far as external heat is concerned, it appears that many climates now thickly peopled would have been desolate with cold. But, in consequence of that remarkable expansion which water undergoes, between 38° and 32° Fahr., those portions which are in this state are lighter than those whose temperature is 40°; they are, therefore, borne up through them, and are warmed or congealed at the surface. There they are the first to feel the intense solar radiation which takes place at so cold a body, and thus to be melted by the sun or by the warmth of the breezes that blow over them. But these illustrations need not be extended, for it would afford ample and interesting materials for a volume, to describe the known purposes which water serves in the organic kingdom, every one of them astonishing the mind by the simplicity of the mechanism by which they are produced.

The ministration of water in the organic kingdom is more interesting still. It has been shown that water is resolved into solid forms, when it is cooled sufficiently, and that these are again dissolved at temperatures above zero. But it seems to follow, that there are certain aqueous molecules which it may not require a low temperature to generate, and which may be permanent at temperatures much above the freezing point. These are annular or circulated molecules, of which there are two sorts, one having the axes of the aqueous particles directed to the centre of the molecule, the other having them perpendicular. If an annulus were once constituted of a single row of aqueous particles, whose axes were in the same plane, and as so many radii from a centre, it would not readily be dissolved by heat, for all the aqueous poles are perfectly free to entertain a very high degree of calorific excitement, without mutual reverberation or restraint, and any movements which might arise at the edges in equatorial union, would, in all probability, be unable to destroy the cohesion that existed, arising from the attachment of the individual angles, and the circulation of the polarity. A snow-flake is thawed at zero, not only because much of it is constituted of individual particles of water adhering here and there accidentally upon the symmetrical frame-work, thus causing its whiteness and opacity; but every one of the radii has its subtile matter polarized, and when, by an increase of temperature, the energy of the repulsion along the axis becomes greater than the existing cohesion among the particles, the extreme particles are repelled and thrown off, and the whole is resolved into water. But an annular molecule is an axis bent into a circle as described already, and the effect of the subtile matter in such a state, is to impart greater cohesion and stability. The molecule in which all the particles implied in it, have their axes in the same plane, and disposed as radii emanating from the centre, may be called *tubular*, because a number of them symmetrically united constitute a tube. The number of aqueous particles necessary to constitute it is variable, but cannot, in any instance, be expected less than twelve. The second permanent sort may be called a *Cellular molecule*: it is the senate, Fig. 34, and is constituted of six particles, having a hexagonal opening in the centre. The action of heat is, in this case, still less injurious than in the other, and the circular form equally prevents the institution of a repulsive axis to dissipate the aqueous particles. A tissue of such molecules to any extent may be constructed, in which not more than two can be found in a straight line, and the symmetry of the whole will be very great. It is not difficult to see that these molecules must often be developed in nature,—and first of the tubular.

When a quantity of water or vapour is resident over any surface of a dissimilar nature, the aqueous particles must be very contiguous to it, and though their heat may cause a recoil as often as they touch it in the direct line of their poles, yet it will certainly often happen that particles of water shall become attached to the bottom and sides of the pool, well, or vessel which contains the liquid, or to any body which happens to be there. The power of cohesion at temperatures such as from 7° to 15° cent. or 45° to 60° Fahr., which are most highly compatible with a quiescent state of the water, may be adequate to institute this attachment of itself; but it may be greatly aided by a certain chemical affinity or difference in electrical state, between the aqueous particles and those of the solid body contiguous to them. A mass of aqueous particles in the tubular condition, will also exert a powerful influence to dispose to the evolution of more water in a state of arrangement similar to its own.

The edge of cohesion being, in all bodies whatever, of equal length, that of the equator of a particle of water must be conformable to the edge of any body which happens to be contiguous, and the adhesion may, therefore, be perfect any where. On surfaces from which trihædral angles project, water may also be attached, by the insertion of a trihædral angle into its pole, and, in this case, the attachment will be very strong. When a particle has been any how attached, and its electrical state more or less changed by the contact, another will naturally attach to its equator. The diameters of two particles of water thus attached are in a straight line, and constitute a polarized axis. This must be positive and negative at opposite extremities. Whatever, then, be the state of the surrounding water, as soon as any particle in the neighbourhood is thrown out of its position of symmetry, it cannot escape being attached to one extremity or other; and thus the line of attached aqueous particles increases till the axis acquires its true length compatible with the temperature, with the subtile state of the surrounding medium, or of the substance to which it is attached, and with other circumstances which will determine its species, or the number of particles that can subsist united.

Beyond this, should any particles be accidentally added, they will again be discharged; nor, indeed, could we conceive the axis itself to possess any permanency when the excitement which generated it is over, if it were necessitated to continue as a polarized axis; but it is evident that the only position in which it can do so is when the equators of all the particles are in one straight line, a condition, where their number is considerable, that cannot be expected. In all other cases, the consecutive poles, proper to the two extremities, will bend round towards each other as much as possible, and as soon as a sufficient number of particles has been attached to admit of the circuit being completed, the opposite poles must unite, and a *tubular molecule* attached to some solid body be generated. Even supposing that the number actually attached were too few to admit of their bending into an annulus, the contiguous particles of water will be speedily involved to complete the circuit, in which the subtile matter will circulate, producing neither considerable attractions nor repulsions among the particles themselves.

One such annular body evolved, and its permanency secured by its structure, will facilitate the evolution of others of the same species in its neighbourhood; so that, the conditions favourable for development remaining the same, the production of the second will be more easy than that of the first. Those which have been evolved will then assume a symmetrical position in relation to each other, and thus they will constitute a fragile cylinder or tube, which may either continue attached to the solid body where the deposition commenced, by that one to which they aggregated, or may be detached, and come to the surface to the air and light. Where one was developed, doubtless many others would be also, as the developing cause must extend over a great quantity of material. Thus, there will ultimately result a fasciculus or group of spicular filaments of a vitreous or watery lustre, and frangible across the axis. Through the interior of the spiculum, were it pervious, water will be transmitted with great force, and in that region it will necessarily be very much agitated by the calorific repercussion to which it will be exposed in traversing this tube, so beautifully studded within by very hot points acting violently upon every body contiguous, except upon the walls in which they are inserted. When any accident occurs to prevent the free transmission of the water, or when the electrical state of the medium is changed, so that a tube, which must be a polarized axis of the given length, can no longer exist, these annuli will be thrown off from one or both extremities, and, being similarly excited with it, they will necessarily move away from the pole which disengaged them to some place of repose. There, losing their unipolar state, they will, in favourable circumstances, dispose to the developement of others like themselves; and thus, out of every annulus disengaged, a fibre will be reproduced similar to the parent. In the state of annuli, it is not improbable that they may often rotate in water, as if they were spheroidal molecules.

Such are the phenomena which must be taking place in water at the temperatures at which it possesses fluidity, yet not excessive mobility and mutual repulsion, and it is interesting to inquire, whether we find any evidence of such phenomena in nature. That a tube, whose circumference consisted only of twelve or fifteen particles of water, should be visible under any power of the microscope, is not to be expected, more especially when possessing sò hyaline a structure as a tube of water. But it is probable that a much greater number of aqueous particles will be almost always implicated in the structure of such spicula, and still more, that a compound spiculum may be developed, composed of a fasciculus of single ones; and it is certainly worth inquiring whether such be not visible. Now, when we carry down our microscopic observations to their ultimate limits, we meet abundantly with most minute spicula, adhering to the grosser, yet very minute, filaments of marine and fresh water algæ, to straws, leaves, and similar bodies, that have reposed for some time in water; and these spicular and filamentary productions possess such characters, that here, not less distinctly than in the forms of snow, does nature respond to the views that have been advanced. Happily, these bodies have of late excited much of the attention of naturalists, being sometimes claimed by the botanist as his property, sometimes by the zoologist; while at other times both parties seem not reluctant to yield to the other, objects whose natural history remained so perplexing. The most elementary species are included in the order *Diatomeæ* of Agardh, of which about fifty different forms have already been described in Agardh's "Species Algarum." This botanist gives the character of the order at some length, of which the following is a part: "DIATOMEÆ. Corpora variæ formæ, plana, crystallina in frustula secedentia; corpora crystalliformia, lineis plerumque rectis circumscripta, atque aut aciformia, aut quadrangula, rarius linea curva circumscripta; cæterum plana, rigida, fragilia, in varias formas aggregata; aut nimirum in parallelogrammum aut in circulum aut apud superiores in filum; ex qua compositione suo quodque modo sæpe maxime singulari solvuntur." &c. "This family of ours," he adds, "forms the transition from the inorganic to the vegetable kingdom, as the Nostochinæ and Confervoidæ do to the animal kingdom. It includes vegetating crystals (crystalla vegetabilia) bounded by straight lines, and aggregated into a mass, which is still crystalliform, differing from minerals only in this, that at last they depart in individual portions." The manner of their departure in annuli is certainly not less singular than it is curious to observe, but it is only a specific mode of effecting what every crystal does when it dissolves, decrepitates, or evaporates. Each of these frustula is a molecule of the body, and the necessity of the phenomena observed, follows from the laws of material action

To obtain a very perfect representation of many of these diatomeæ, it is only necessary to lay down a slender prism of nitre in a saturated solution of the same. On different regions of the sides, groups of slender spicula arising from a common origin, and disposed in radiating pencils, in parallelograms, and sectors will appear, as like as can be well imagined (though doubtless much more rude) to those crystalline fibres, which are every where met with upon the fronds of the capillary algæ. Nor will these spicula of nitre be found more permanent than the others, if the physical condition of the medium be changed. An increase of temperature will remove molecules from their extremities, which cannot again be lengthened by depressing the temperature. The saline molecules rather give rise to new filaments, and, if their quantity be considerable, and that of the solvent small, the nitre cannot be prevented from stretching up in aborescent forms over the walls of the vessel which contains it, like a Jungermannia, a Vaucheria, or an, Oscillatoria. Were we to construct synthetically, by combining aqueous particles, molecular forms to illustrate these views, we should constantly evolve forms quite similar to many of those figured as algæ. Let the reader only inspect the Diatoma tenue, flocculosum, fenestratum, marinum, arcuatum, auritum, &c. the Fragillaria unipunctata, hyemalis, &c. the Echinella fasciculata, &c. of Lyngbye's Tentamen Hydrophytologiæ Danicæ, or many of the Fungi and Algæ of Greville's beautiful Cryptogamic Flora, and he will find all that could be wished to illustrate the structures of water now contended for, as the scaffolding of these merorganic bodies.

The other remarkable family, the Nostochinæ, alluded to by Agardh, includes substances consisting of filaments or groups of particles, which are enclosed in a tremulous mass like a gelatinous hydrate; and that such gelatinous matter should be abundant, we will not deem strange, when we remember how small a quantity of that universally abundant substance, silex, reduces pure water to the state of tremulous jelly, and how easily water is otherwise reduced to the gelatinous state. The included molecules and fibres in this case, however, are generally much more highly organized than in the diatomeæ, and often seem to perform movements more analogous to those of animal than of vegetable functions. Treating of them, Professor Agardh says, "the crystalline and rectilinear form, the vitreous lustre and rigidity, all which placed the former on the limits of the inorganic kingdom, have disappeared. We have entered on the confines of the animal kingdom. It begins by an organic gelatine, but, as is the case in the preceding family, it is to be remarked that the individuals are not free, but are grouped together into a community of a definite form."

The movements which are exhibited by the included fibres and molecules, are generally those of oscillation, or some modification of systole or diastole, by which the excitement of subtile matter is transferred. There is sometimes a deliberate oscillation through a certain angle, as in some oscillatoriæ; at other times, as in some of the diatomeæ, two filaments separate and unite; but in none have I remarked a more singular movement than in the molecules included in a large gelatinous mass, of a light green colour and conglomerated form, which is abundant in the stagnant water of moss-pits.* These molecules are disposed in the circumference or arch of a circle, and they vary in their form from oblong to oblate. They all possess the same shape at the same time, and though they are separated from each other by their gelatinous nidus, they all commence at the same time to stretch out in the direction of their axes, which are parallel to the radii of the arch in which they are disposed; and, after a somewhat deliberate movement outwards, their form being lengthened by the whole distance which the preceding extremity moves through, they all suddenly shrink back to their oblate figure. This movement was continued without intermission as long as I observed them.

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* It is, if I remember right, figured in the work on INFUSORIA of Müller, an admirable naturalist, whose works contain sounder views of natural science than were popular in his day, and anticipations and detailed accounts of many species of invertebrated animals, and other discoveries, which have been since appropriated by others.

Although such bodies no doubt possess a structure very complicated compared with any which can be immediately conjectured, yet perhaps their structure may one day be discovered. We will not long consider them as composed of water only, if we suppose that there exist within them, or diffused in gelatinous nidus, any tubes or cells constituted of water. The energy of such an apparatus to decompose water must be extreme. Chemists are often able to decompose bodies in immense quantities, such as cubic inches, by passing them through red-hot tubes of considerable diameter. It is impossible to assign limits to the decomposing energy of such a minute tube as one composed of annular molecules of water, acting perhaps upon a single particle within. It is not improbable that some particles might even be resolved into radiant matter itself; in which case, as will be afterwards shown, the organized being becomes fit for having that power lodged within it, which makes it to be an animal or sentient creature. If it be asked whether such bodies generally are to be called crystals, plants, or animals, it may be remarked, that the ideas vulgarly attached to any of these terms (and vulgar ideas must always regulate the use of common words) do not apply to these merorganic forms. Meantime it is a matter of greater moment to investigate their origin and natural history.

The cellular molecule of water (Fig. 34.) seems to perform an office in the vegetable economy yet far more important than the tubular. It is difficult to see how tubular molecules could be generated in confined places, such as in the germinating seeds of plants, or in the vegetable structure subsequently evolved. But cellular molecules are of most easy production every where, and, doubtless, wherever six particles of water, and no more, are contiguous in any region, they will unite into a cellular molecule; for, by doing so, they acquire unity and symmetry. Now, except the carbon of plants, which will be afterwards treated of, chemical analysis shows that almost the whole vegetable tissue consists of oxygen and hydrogen, in the proportions which constitute water; and as these bodies, so far as we know, are never presented to each other, in such circumstances, without forming water, it is very reasonable to conclude, that the vegetable tissue, except in as far as it is carbonaceous, is aqueous.

It will afterwards be shown that the frame-work of the spiral vessel, the woody fibre, and vascular system generally, is in a great measure composed of carbon. It is no less apparent that the mould of the cellular tissue is in a great measure composed of water, and it is easy to see that cellular molecules united into laminæ and interlaced, will give rise to the very structure found in cellular plants, as far as that can be discovered. The apertures in the centre of each molecule which are isamorphous with the equatorial projection of a particle of water, will be large enough to transmit hydrogen, oxygen, and carbon, but not water; and this is perhaps letting us as far into the mystery of secretion as can easily be effected. Suppose a quantity even of pure water to find admittance into a cell on the surface of a leaf, the heat which may be generated there by the light, as has been shewn, may be very great. The aqueous particles cannot escape from the fire which surrounds them on every point, for it is to be remarked of these cells of aqueous tissue, as was formerly done of the tubular tissue, that the aqueous poles vibrating at right angles to the walls, may be intensely hot, without occasioning any dissolution or injury to the walls themselves. As soon as a particle of hydrogen is evolved, it may escape through the hexagonal apertures into a colder cell, and be relieved. The oxygen may do the same, but most probably, in consequence of its dissimilarity of motorial state, it will be solicited to another route, and one or other, while separate, may unite with carbon, and thus the return to the state of water be prevented, and a volatile oil, or more perfect forms, such as sugar, starch, or malic acid, be generated.

Were the organic pores of the cellular tissue no larger than the diameter of a particle of water, they would be very much beneath being visible; nor could we hope that any microscope, however perfect, could enable us to see them. Probably they would be much less than one millionth of an inch. Only a single ray of light could be transmitted through them, while the lumeniferous excitement of the three others entering into the structure of a perfect ray, would be detained on the farther side, and interference and darkness would doubtless ensue. Many microscopic observers have thought that they saw, organically distributed, pores in the walls of the cellular tissue; and that this is the case in many regions of the vegetable tissue cannot be doubted: but the pores seen in the young pith, and wherever they are generally said to have been detected, are, in reality, little globules of transparent starch attached to the walls of the cells. The refraction which they occasion in light, transmitted at a distance from the axis, produces the appearance of a dark border surrounding a lucid pore, so that there is really a *bourrelet saillant*, as M. Mirbel describes, though of a nature somewhat different from that which that physiologist supposes. That these seeming pores are really minute globules of starch, is proved by the fact, that they may be washed off from their positions, examined on the glass, and dissolved by warm water. In many cases, however, their distribution is so regular, and their aspect so hyaline, that it is not wonderful that they have been considered as real pores.

In the vegetable structure we observe a most beautiful development of the numbers determined by those of the aqueous particle, which may be said to belong to the *ternate system.* Not to mention the hexagonal form of cells, and such forms which would arise from the compression of cylinders and spheres, it is not to be forgotten, that plants, in which the cellular or aqueous structure is most abundant, are characterised by a most singular peculiarity, hitherto deemed very marvellous. The number three constantly appears in the forms of their stems, the fibres of their leaves, and still more beautifully in the parts of their fructification. Their stems are often trigonal. There are always three parallel nerves traversing the leaf. The corolla usually consists of three partitions or petals: there are usually three stamens; three locuments in the seed-vessel. Where any organ appears single, the rudiments of the other two are generally to be traced; and when the number is more than three, it is always a multiple, such as six or nine. It will afterwards be shewn, that there is an equally good reason for the prevalence of five, and its multiples, in the dicotyledones or more carbonaceous class. Where the structure is still more imperfect, and the variety of constituent matter great, there appear only the numbers proper to subtile matter, the circle and the axis, infinity and multiples of two. This is beautifully displayed in the peristomes of the mosses, the cruciate and binate arrangement of the seeds in the ulvoideæ, and many other tribes of plants. It is also displayed in the simplest animals, as in those coloured bodies in the medusidæ, which are distributed between their axes and circumference. It has been detected in the fungi by the learned Fries, and forms the basis of his Systema Mycologicum, nay even of a quaternary system, which he extends to all nature. The Pythagorean oath of the Τετρακτὺς, then, is not to be disesteemed. The circulation of subtile matter, however, which obtains in organized forms, tends constantly to overcome these dispositions towards certain numbers connected with the forms of the matter out of which the organized body is constituted.

It appears, then, that water performs, in the economy of our world, the most curious and interesting purposes; and having said so much of the part which it occupies in the microscopic world, a few words may be added of its probable existence in the regions of the telescope. In the regions of space this instrument unfolds stars and planets, comets and nebulæ. These celestial bodies very naturally divide themselves in two groups, into Stars and Planets, which we may study by analogy of the earth and sun; and into Comets and Nebulæ, which are, in many respects, different from the former, and similar to each other. With regard to those nebulæ which are not clusters of very distant stars, all that can be discovered is, that they are composed of matter in a state more or less analogous to vapour; and, as it is the simplest hypothesis, so we may entertain it till something appear to the contrary, that certain nebulæ are volumes of aqueous vapour interlaced with the radiant medium, which is indeed saying nothing else than that they are immense clouds in the sky. Water is the true protogyne of nature; and to pass over water and assume that no nebulæ are constituted of it, would be unwarrantable. If aqueous nebulæ are not attracted to some dense body, it seems to follow that they shall tend to aggregate into drops of dew, or flakes of snow, and shall at last be consolidated into an aqueous or glacial mass. The observations of the admirable Sir William Herschel, in his "sweeps" of the heavens, led him to conclude the consolidation of nebulæ*. Masses thus constituted could certainly overcome the resistance of the radiant medium (for, until they rotate, that medium must occasion resistance), and proceed towards the stars in their neighbourhood, and, in most cases, perform a circuit round them. It might be thought that they should often proceed directly to the centre of attraction, and their orbits thus be destroyed; but to produce such a catastrophe as this, it is an essential condition, that they shall not only be directed upon that centre at first, but suffer no lateral attraction during their progression, which is an extremely improbable case. If the course of the advancing mass be in any degree oblique to the direction of these radii of light, then they will act upon it so as to direct it away from the point whence they emanate, producing phenomena analogous to a wind blowing from the radiant object. The course of the mass will be the resultant of the two forces, that determined by gravitation and the radiant repulsion; and, as these forces are in the same ratio every where, both increasing in the inverse duplicate ratio of the distance, its course will be a true conic section, and its direction around the sun (provided it have no rotation of its own) may evidently be direct or retrograde, or any other way whatever. One perihelion passage will not, however, necessarily imply the institution of a regularly returning orbit, because the matter of the cometic mass must be more or less changed by a perihelion passage, and if the condition of its matter be changed, it will no longer act as before. If such a mass should circulate around our sun, by-and-by, at a certain degree of nearness, it might become visible, from the reflection of his light; and we are able to assert, pretty confidently, the phases which it would necessarily assume. It would be surrounded by a vapoury atmosphere, whose quantity would depend on its vicinity to the source of heat. But whether we conceive its nucleus to be water or ice, its evaporation would evidently be a very slow process, in consequence of the inability of water to transmit heat downwards. The experiments of Count Rumford prove that the surface might be made to boil by the solar heat, while, at no great depth, the water would be comparatively cold. The smaller the mass, it would pass into the state of vapour more easily, because the weight of its particles would be less; and, if it did not possess a certain quantity of matter, probably the whole would very speedily be converted into vapour. When it approached the sun, its vapoury atmosphere could not be spherical, but would be extended into a coma behind the nucleus, where it was secure from the impulsion of the sunbeams, and were it of a visible nature it might be illuminated by the tangent rays. Were it pure steam in a state of perfect symmetry, however, it follows, that the whole coma should be invisible; but the external confines must be cooled, and have many interferences with the radiant matter, which will destroy the symmetry there, and render this part visible. We should therefore expect the coma of such an aqueous mass to be more or less perfectly the frustum of a cone (of which the sun is the imaginary apex), opaque externally, and transparent within. When the mass is proceeding in that region of its orbit, so that the coma lies in the radius vector rather than in the orbit, that is, in the region of the perihelion, it is evident that the summit of the coma must be bent away by the resistance of the radiant medium towards the region which it has left, like the summit of a plume waved in still air. Moreover, the course which the vapour would pursue in escaping from under the sun to the coma's shadow, must produce the effect of a lucid canopy on the aspect facing the sun, for it is from this aspect that the vapour will be chiefly raised; and, as soon as it has attained a certain elevation, it will be reflected by the intense sunbeams as a *jet d'eau* is by gravitation, and find its way into the coma. When the whole nucleus is evaporated, this lucid canopy must, of course, disappear, and the whole constitute a pencilliform, or spheroidal nebula. As it recedes from the source of heat, these phenomena will be produced in an inverse order.

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* But it is not to be forgotten, that all his observations on which this view is founded were made on *luminous*, not *dark* nebulæ; and the phenomena may be equally well explained on the hypothesis, that nebulæ giving out light are returning to the state of light.

Now, this is a relation of the very phenomena presented by comets, and as it is the simplest and most natural supposition, so every phenomenon which they exhibit countenances the idea, that they are in a great measure, in many cases wholly, composed of water. The number of comets which have been observed to perform circuits around our sun is very great; but when we consider that they must be large before they can be visible, or can perform such a circuit, we shall regard the comets of astronomers as but a small fraction of those which are connected with our heavens more intimately than those of any other system.

Of comets, some return regularly like planets, others are no less strangely found to be amissing at the time when they are expected. There is nothing more instructive as to their true nature, than that they should move through the heavens in every direction; and, as will be afterwards shewn, this forms a very powerful argument for their aqueous nature. Some philosophers have inquired into the probability of a comet's attaching itself to the earth; some have thought that they found the records of such an event in the crust of the earth, and even pains have been taken to calculate, that after many millions of years, this globe will suffer some wrong from such an accident. Nothing seems more probable than that a planet should, in the course of ages, receive the addition of the matter of a comet to its own; and if it be the nature of water to be converted, in the course of ages, into solid bodies, such an event, or something equivalent, must be required to sustain the planet's organization, though it may, in the first instance, deluge it. Should a comet be attracted towards a planet possessing such a temperature as the earth, we should probably obtain evidence of its approach or not, according to its magnitude. When within a certain distance of the globe, unless it were directly incident, it would revolve when at a certain degree of proximity around it, producing immense tides in the ocean in consequence of its attraction of aggregation as well as gravitation, and would begin to be distilled over as mist, clouds, and showers. An unusual rain would increase to a certain maximum, and then gradually "assuage;" and when the whole nebula was received by the earth, the sky would clear up and permit the sun to shine upon the deluged planet. Comets and some nebulæ, then, are merely the mists, hailstones, and raindrops of the ethereal expanse, analogous to those of the earth's atmosphere.

Pure water, when kept in an insoluble vessel, is a very permanent body. But this can only be said of it when its electrical state remains undisturbed. One of the most curious features connected with its structure, is the ease with which it may be separated into two bodies capable of being developed in a singularly easy manner by the two electricities. Every particle, which is at once strongly electro-positive in one region, and electro-negative in another, can at once be resolved into two, one of which is very highly positive, and the other very highly negative. Suppose, then, that two wires, from the poles of a galvanic axis, are brought near each other, and that a particle of water is placed in the focus, it is solicited opposite ways. In virtue of being positive, it is drawn to the negative pole; and in virtue of being negative, it is drawn to the positive pole. It immediately fulfils the conditions of its state, by giving one particle of hydrogen to the negative pole, upon which the remaining five particles immediately resolve themselves into the only symmetrical form that is possible, without a great change of place, and which is also the most highly negative of all bodies, and satisfies most perfectly the demands of the positive pole. Thus, from the destruction of every particle of water, one of hydrogen seeks to the negative pole, and one (*b*, Fig. 37), evidently of very different structures and properties, to the positive. If there is no body in the way, these bodies may be seen escaping in bubbles through the water, but the hydrogen only can be collected pure. The other, when prevented from uniting with the hydrogen, immediately on coming into the region of the radiant medium, attracts an atom into its pole, and has no longer such an excessive affinity for hydrogen, but they may exist together for a long time without uniting. If this body has not thus its pole occupied by radiant matter, as soon as it arrives in a region of electrical equilibrium, it constantly unites to hydrogen, when both are simultaneously disengaged, and a particle of water results. Hence the decomposition of water into the two free gases now considered is probably only a chemical experiment, and never occurs in nature to any great extent. Water is, indeed, frequently resolved into the form in which a particle of hydrogen is drawn out, the electro-negative form being on its pole (*c*, Fig. 39), and the form prevented from returning to the common state of water, by either pole being engaged with some other body. It is to be observed of water in this form, when the engagement is at the hydrogerent poles, that it possesses the property of discharging true colours, or such as arise from a chromatic axis. The naked pole probably receives the extreme atom of the chromatic axis, which of course is completely destroyed, for the edges of the extreme atoms that are left must be parallel,—an arrangement on which polarity and the resulting colour cannot take place. We shall find that this arrangement obtains in deutoxide of hydrogen, in sulphurous acid, and the aqueous solution of chlorine.

Water is decomposed when it is placed between the poles of an acid and a metal, with whose calx the acid unites. These bodies, the metal and acid, are in opposite galvanic states, and they are further aided in decomposing water, by the metal's demand for an electro-negative form, and the acid's for the resulting calx. The common metals, as will be afterwards seen, are parasitic forms conformable to this electro-negative body, and having a vehement affinity for it. Hence they exert a disposing influence to induce the water into a state, both as to form and electricity, consecutive to themselves, that is, into the state of this body, while the hydrogen is suffered to escape, and is replaced by the acid. It could not be asserted, however, that in the action of such an acid as oil of vitriol upon a metal, every particle of water suffered resolution into these two forms. There cannot easily be less hydrogen than the just quantity, but it is very probable, that some particles of water, when the quantity of calx generated is great, may be wholly resolved into hydrogen. To this, the presence of much electro-negative matter would dispose, and the demand of the metal for such matter might not wholly prevent it. In such experiments, then, there will probably be found a small excess of hydrogen. Oil of vitriol, and muriatic acid, would be more apt to split water into hydrogen in this way than nitric acid; for these two acids insert themselves into its poles, and exert a stronger influence upon three particles of hydrogen, than upon the other three, but nitric acid cannot find access to the poles of a particle of water.

The resolution of water into these two bodies, can only take place to a considerable extent where the frustular may unite with some other body. When the pole of this form is naked, the hydrogen, newly disengaged, is again attracted, as soon as both are removed from the decomposing focus. Hence water at the bottom of the ocean, though decomposed into these two bodies by galvanic energy there, would be recomposed before the gaseous elements had gained the surface; and therefore, if this electro-negative body be found in the air in great quantities, it cannot be obtained by the decomposition of the waters at great depths, into these two forms.

When a vigorous galvanic state is induced in a quantity of water, besides the gases evolved, certain substances make their appearance, of an alkaline and acid nature, which has excited much of the interest of experimentalists. Of these, none is more curious than soda. Sir H. Davy obtained notable quantities of soda from pure water contained in an agate cup, which did not yield any on analysis. He satisfied himself, however, that it was derived from no other source than the cup, because he did not obtain any, when the water was acted on in gold vessels. But the silica of the agate has a great affinity for soda, and would dispose to its evolution according to well known and acknowledged principles, while gold has no such affinity. Hence, though soda was not developed in the gold, it does not follow that it was not developed in the agate. It is scarcely to be expected, however, that sodium should have been generated in notable quantities in such small experiments: it is, indeed, one of the forms of most simple structure and easy development; but it would require very unequivocal evidence, before we should assume that it has been produced in the laboratory of the chemist.

The two electrical resultants of decomposed water that have thus been elicited, are the most active and most perpetually recurring of all bodies. The one, by itself, in various arrangements, produces some most interesting substances, while the other is a constituent of almost every natural body.

OF OXYGEN.

When a particle of hydrogen is removed from one of water, the spendyloid form which results (Fig. 8 and Fig. 37) is named Oxygen; its atomic weight is 10; its form is a pentagonal prism, the opposite edges of the base and summit being in a transverse position to each other, and the prism being terminated on both aspects by a concave or negative pentagonal pyramid. Like water, its centre, which is absolutely cold, is exposed; and its form is so ill adapted for sustaining a state of considerable vibration, that its specific heat must be very small, and its attractive energy and weight consequently great. The facets, supposing the five contituent hydrogens to retain their form, cannot be perfectly in contact, in consequence of the inability of ten atoms of matter, or five particles of hydrogen, to apply themselves to each other perfectly in this position. We may indeed suppose that matter is soft enough to yield a little, so as to produce symmetry and solidity. It is more probable, however, that the angles only yield a little, and that the particle is, consequently, in a state of constraint, which will aid in explaining the ease with which it changes form, and becomes water when a particle of hydrogen is supplied to it. Its electrical state is the most highly equatorial, or negative, of any body, and its external edges and concave pentagonal poles are conformable to a great many substances. Hence it is never met with in nature in a free state, nor can it be insulated in the laboratory, for it always affects the aëriform state, and, thus exposed to the incidence of radiant matter, an atom perches in its pole as hydrogen does, and the oxygen becomes vital air. Its properties are consequently unknown. It obtained the name of *oxygen* from the belief that it was the principle which generated acidity; but it is essentially a part of the fixed alkalis, as well as most other bodies, whether acid or alkaline; and some of the strongest acids, such as spirit of salt and vinegar, derive their acidity from the union of hydrogen with their base. The Greek radical of the name, however, expresses also activity, and is therefore still descriptive of oxygen, though, as is well known, it cannot now be regarded as the acidifying principle.

Oxygen is very abundantly diffused in nature; it constitutes a large part of all siliceous, calcareous, and ferruginous stones and rocks: it is abundant in animal and vegetable bodies, and constitutes rather more than a fifth part of the atmosphere. There, however, it exists in the only form in which it can be obtained by the chemist, viz.,—

Vital or *Empyreal Air*.—When we consider the unipolar electrical state of a particle of oxygen, and the susceptibility of an atom of the radiant medium contiguous to its pole, to have an opposite state induced upon it, we will not hesitate for a moment to believe, that, as soon as oxygen mingles with radiant matter, it will unite with it as it does with hydrogen, by receiving an atom in its pole. But, in this case, there will evidently be no destruction of the form of the oxygen. Two such particles, each charged with an atom of radiant matter, will immediately place themselves so as to cover each other's naked poles, and constitute a symmetrical molecule, formed by two particles of vital air, as in Fig. 38.

The absolute atomic weight of a particle of vital air, then, is 11; of a molecule 22. The relations between the atomic weights of this work and those of other systems, will now be seen. According to the views of Dalton, the atomic weight of hydrogen is assumed as unity; that of vital air is regarded as 7, because this is supposed by him to be the weight of the oxygen which unites with 1 of hydrogen to form water. Sir H. Davy, not insisting upon the atomic views of Dalton, agreed with him in making hydrogen the unit; but the proportional number for oxygen he regards as 15, because a volume of vital air, equal to one of hydrogen, which weighs 1, is believed by him to weigh 15. The views of Berzelius, who, like Davy, has respect to equal volumes, are the same; but he wisely transfers the initial number from hydrogen to vital air, or oxygen, making the latter 100, and hydrogen 6.2177. Wollaston agreed with Dalton, in making the atomic weight of oxygen correspond to half a volume of the same, and this he has the happiness to make 10, while that of hydrogen he regards as 1.32. Prout reduces the ratio of these two bodies to that of 8 to 1, or 1 to 1.25, and these are the fundamental numbers of the system of Thomson. As no distinction is made by these philosophers between vital air and oxygen, the notation of Berzelius, Wollaston, Thomson, and most chemists, does not always agree with that advanced in this work. When their atomic weights are raised from the specific gravities of the bodies considered in the gaseous state, or compared with that of vital air, to be suited to those of this work, they must be increased in the ratio of 10 to 11, or multiplied by 1.1.

As it exists in the atmosphere, where it must possess its most perfect condition, the specific gravity of vital air is probably rather more than 1.111; but different chemists assign different specific gravities. 100 cubic inches, were they collected and weighed, would balance about 34 grains. The most careful experiments give from 34.7 (Saussure) to 33.6 (Berzelius and Dulong). Oxygen, could it be preserved from union with radiant matter, would possess a specific gravity nearly $\frac{1}{11}$th less, or 1.010; and the same volume would weigh, in round numbers, about 31 grains. The radiant matter in the poles of the oxygen is very free to vibrate, and will be warm, and will add something less than $\frac{1}{10}$th to the weight of the oxygen. The specific heat of vital air must still be very small, though greater than that of oxygen; it gives little interruption to the transmission of light, and possesses a very small refractive or exclusive power, which might be expected from the form of its particle.

The number of *molecules* in a cubic inch is the same as in hydrogen; hence the number of *particles* is double. It might be thought that particles, such as those of vital air, so heavy compared with hydrogen, ought to be more dense under the same pressure; but their energy of mutual repulsion increases in the same ratio as their weight, for every atom added gives its repulsive as well as attractive fluid to the mass, and though differences of form might naturally produce small differences in the balancing of the two, yet the force of symmetry belonging to the surrounding radiant matter disposes their centres always to occupy the same positions, so that generally equal volumes contain an equal number of insulated particles. If an excessive repulsion or want of buoyancy render this impossible, the law of symmetry demands that the gas shall occupy every alternate cavity, or half or double the number of the first. The exceptions to this are extremely few, and occur in aëriform bodies, from which, perhaps, the radiant matter is almost entirely excluded, such as the vapour of sulphuric ether.

The electrical state of vital air is somewhat more quiescent than that of oxygen, as it has now, by the aid of the accessory atoms, acquired a positive axis. Hence its demand for union is not so vehement. Many bodies, indeed, which have a strong affinity for oxygen, can decompose water more readily than unite with vital air; and hydrogen itself requires to be aided by a high temperature, before it can find access to the pole now occupied by the atom, and resolve the whole into water. Whether this union is effected by the departure of the atom of radiant matter to give place for the hydrogen, or by an opening up of the molecule of vital air into two particles, so that the hydrogen finds its way to the naked poles before covered in, it may be difficult to determine. The latter seems more probable.

In this way, it is evident that any quantity of these gases vital air and hydrogen, if mingled in due proportions, may be wholly resolved into water, the radiant matter being disengaged; and it is no less evident, that the proportions required are an equal number of particles, or half the number of molecules of vital air, that is half the volume. During the union there is evidently a very violent movement in every particle, which generates a violent state of tremor or heat, a part of which is retained by the aqueous atom, and a part is given off to surrounding bodies. Thus, as the capacity for entertaining calorific excitement of an aqueous particle is much greater than one of oxygen, means are provided for developing it at the moment when the water, with its increased capacity, is generated. In cases of violent chemical action, luminous rays are almost always instituted in the radiant medium. It is evident that it must be thrown into a state of excitement where the action is going on. Here, however, the light propagated is less than in many other cases, partly on account of the great heat which is adverse to lumeniferous propagation, as already shown, partly because there is no opaque body where the action is going on, to form a base to the rays of light, and render the flame visible. The most simple manner in which hydrogen and vital air may be made to exhibit their union and the resultant water, is by permitting hydrogen to escape by a small aperture into the air, and heating the matter around it by bringing a flame into it for a moment. The jet assumes a spindle form, the axis being longer or shorter according to the velocity of egress; and in the confines of this jet with the atmosphere the union takes place. The water generated is carried up as steam by the ascending current of air, which is heated by proximity to the flame. The surface of the hydrogen burns, and this fiery stratum forms a capsule to contain it, and prevent it from dissipation in the air, till it shall have been burned by passing through.

The structure of such a flame then, is very beautiful. The internal part is hydrogen, or the combustible gas whatever it may be; then there is a stratum of burning gas, then one of water and vital air, then nitrogen, and then the atmosphere. Such an arrangement as this, where so powerful a chemical action is going on, must evidently be in a state of developed galvanism, the positive region being, as in other cases, the region of most violent action. That such is really the case, has been shewn by the researches of M. Pouillet, who found the axis of the flame negative, the peripheral region positive, and the neutral circle in some intermediate position.

Besides water, which is almost the only product of this combustion, it appears that some nitrogen is always generated, —a result which is only to be expected, as will fully appear when treating of that body.

If vital air could be compressed with sufficient violence, water would also be generated as well as by combustion with hydrogen. By the first stroke, were the atoms on the poles of all the particles brought near enough to unite in pairs, and constitute a particle of hydrogen, half the volume of vital air would condense as water. By the second stroke, which ought not to be repeated till the residuary oxygen has become provided with radiant matter again, the half would again be converted into water, and thus any quantity less than the whole of a volume of vital air, might ultimately be converted into water.

Though vital air exists abundantly in the air which we breathe, yet it cannot be directly extracted and insulated from this source, for the purposes of experiment. It is always procured from some body, in which either oxygen or vital air exists in such a state of easy combination, that it may be disengaged by heat or a superior affinity. It is invisible, and destitute of taste and smell. Combustible bodies introduced into it when hot, burn with great vehemence, uniting with it, and degenerating into a calx or oxide, according to their species. Oxides possess no common properties. They are sometimes acid, at other times alkaline, and some are crystalline, and others aëriform. Chemical substances have received their names in a great measure from their relation to oxygen, but it is the natural use of language to name bodies from some characteristic property; and though the multitude of organized species may render generic and specific distinctions necessary in zoology and botany, yet there is not the same urgency for these refinements in chemistry. It is to be regretted that the names given by the fathers of the science are so completely forgotten; for it is not right, without some good excuse, to change a name which has been given by any one to the substance which he has discovered or first described. Nomenclature of bodies, founded upon the products of their distinction or analysis, must constantly change with the progress of the science, and, at best, can only remind us of certain chemical, not natural, properties which they possess.

Vital air is essential to respiration, but these phenomena will be treated of afterwards with more propriety, under Carbon. Most other gaseous bodies, when breathed, speedily occasion disorganization, even though vital air enter the lungs at the same time. But nothing can supply the want of vital air. Without it suffocation sooner or later is induced. Neither can plants exist in regions from which it is excluded. It is the cup in which light is handed to sustain the functions of life, and from the simplest plants to the pulsation of our heart, all is dependent on the presence of vital air. As already mentioned, it constitutes rather more than one-fifth of the atmosphere. It is absorbed by water in very considerable quantities, and is always found wherever there is a medium suitable for the life of an organized body.

Deutoxide of Hydrogen.—By a peculiar process, oxygen and hydrogen may be retained in a state of union, each possessing its specific form, and the substance which results possesses very interesting properties. It consists of two particles of oxygen, one on each pole of a particle of hydrogen (Fig. 39): hence, as has been already shown, it must possess the property of discharging colours. It also disorganizes the skin, and thickens the saliva. It is a limpid liquid of very difficult congelation, and, at the temperature of 15° cent. or 60° Fahr., resolves itself into water and vital air. It is very interesting to observe, that, though it contains already an excess of oxygen, it may become a deoxidising agent,—a fact inexplicable in any other view of the structure of oxygen, than that here given. When presented to loosely engaged oxygen, such as that in the oxides of the noble metals, the same phenomena ensue as if they were exposed to a stream of hydrogen gas. The oxygen of the deutoxide, in its intermediate state between that of oxygen and water, is attracted to the contiguous oxygen, and separated as particles of hydrogen. Thus, water is formed by the aid of the oxygen of the oxide, in sets of five particles for every particle of oxygen in the deutoxide whose conversion into hydrogen takes place. It is to be remarked, that a particle of this substance is that which would result, were a molecule of vital air to be reversed, and the two atoms of radiant matter to unite. It is not impossible, then, that it may be generated in a sunbeam; and to this partly, perhaps, and in some instances, the solar ray may owe its bleaching properties. Deutoxide of hydrogen has been very rarely produced in the laboratory; it owes its discovery to the genius of M. Thenard. The phenomena which it exhibits are perfectly inexplicable on the common chemical hypotheses.

NITROGEN. AZOTE.

It has been already shewn, that when oxygen and hydrogen are placed in each other's vicinity, and in a state of natural electrical equilibrium, water is immediately formed. The decomposition of water on the great scale, is therefore difficult, for the nascent gases, immediately when removed from the decomposing focus, unite again and reproduce water. Hence there might be very powerful decompositions of water into oxygen and hydrogen, at depths of the ocean, and no elastic matter escape at the surface, were water subject only to decomposition into oxygen and hydrogen. For preserving the oxygen which has been developed, it is necessary that both its poles be covered, and the access of hydrogen prevented.

Now, if we consider the structure of a particle of water, we must expect, that, though it be chiefly decomposed into oxygen and hydrogen, another form may frequently result from the five particles of hydrogen left by the departure of the sixth. Such, indeed, must always be the case when a particle of hydrogen is driven out from the centre of the particle of water. But other accidents, such as an aversion in the medium to the development of negative forms, may produce the evolution of the same form, which is much less negative than oxygen. Suppose, by a violent compression in the direction of the equator, that a particle of hydrogen is driven in towards the centre, its presence there forms a mechanical obstacle to the evolution of the form of oxygen, and the five remaining particles are under the necessity of uniting by their apices, and a form (Fig. 12) results, possessing symmetry enough to exist for some time. This is a particle of nitrogen.

To become symmetrical, this body must either disengage the five atoms of matter which project from one side, so as to give rise to the form (Fig. 4), or provide itself with other five to the other side, so as to give rise to the form (Fig. 7). We may suppose that one will do the first, and another contiguous serve itself with the atoms which the first has set free, and thus from two of the unsymmetrical forms (Fig. 12), there result two symmetrical ones, (Figs. 4 and 7). But should two of the unsymmetrical bodies (Fig. 12.) meet, it is evident that they can unite together, and a beautiful, highly symmetrical, and quiescent form, results (Fig. 14). Such are the forms, together with oxygen and hydrogen, which are most immediately derived from the decomposition of water; and that such decomposition must take place abundantly in the ocean, both on its confines with its own basin and the sunbeam, we can scarcely doubt.

The two small forms (Figs. 4 and 7), as will be afterwards shewn, continue in the ocean, but the large symmetrical one (Fig. 14) is aëriform; it is evident that its poles are conformable to those of oxygen; and if two such contain a particle of oxygen between them (Fig. 40), it will be secure from the access of hydrogen, and the whole may emerge at the surface. Its axis, however, where a more advantageous union is afforded to the oxygen, will subdivide, and, at the surface, each molecule will separate into three parts, from which will result one particle of vital air, (now occupying the centre as oxygen), and two molecules of nitrogen, or one binate molecule, or volume of vital air, and four of nitrogen. Now, this is the known composition of the atmosphere.

We are thus introduced to another body composed of hydrogen, which, though itself is somewhat inert and uninteresting; yet consists of two particles locked up, which, individually presented to other bodies, possess very great chemical activity. The atomic weight of a particle of nitrogen is 10. It is, therefore, five times the atomic weight of hydrogen, and this has been already assigned as its atomic weight by Dalton.[*] Its specific heat must be considerable, but, like oxygen, its properties are unknown, as its particles instantly on the nascent state, unite face to face, and constitute a *molecule* of nitrogen, whose atomic weight is consequently 20, or double that of a *particle*.

The gas composed of binate molecules of nitrogen is invisible and tasteless. Its specific heat is said to be rather

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[*] The atomic weights of nitrogen by Berzelius, Wollaston, and Thomson, when transferred from vital air considered as 10 to oxygen, and thus made to correspond to the atomic ratios of this work, gives,

Berzelius,	9.750	
Wollaston,	9.645	× 2.
Thomson,	9.625	
True weight,	10.000	

greater than that of vital air, as we should expect; its magnitude is nearly the same as a molecule of vital air; its atomic refractive power is considerably greater. The specific gravity and weight of 100 cubic inches must, consequently, be less than that of the same volume of oxygen (vital air deprived of radiant matter); and, accordingly, instead of 1.010, or that of oxygen, the specific gravity of nitrogen is found to be about .972; and, therefore, instead of about 31 grains to 100 inches, that volume of nitrogen is found to weigh about 29.76 grains. But, when we consider that no two chemists ever found a volume of the same gas to possess the same weight, we will almost cease to be curious about small fractions of grains. In this gas, indeed, the weights assigned are very uniform; and, besides, nitrogen, common air, carbonic oxide, and carbonic acid, ought to give uniform results, in as far as their own structure is concerned; but when the action of the gas upon the radiant medium is considerable, as in the case of the compounds of carbon, sulphur, phosphorus, and chlorine, with hydrogen, the weights are very variable at different times and places, and in the hands of different manipulators.

Nitrogen is not only developed in the inorganic kingdom by the decomposition of water; it is an abundant product of animal assimilation. While it remains in the organization of animals, however, there is every reason to believe that it exists in a solid state, or as an icosaedron (Fig. 13); and if so, the icosaedron may be regarded as the characteristic form of the animal structure, as the decaedron (Fig. 4), afterwards to be illustrated, is of the vegetable. Carnivorous animals receive it into their bodies as an ingredient in their food, but a greater quantity is found in the blood of the ox than in that of man, though the former is not known to consume any nitrogen at all. It is true, that, at every respiration, a large quantity descends by the windpipe, though not the gullet; but whether absorption take place in the lungs or not, there is positive evidence, that as much, or more, nitrogen is given out, than is inhaled. In these organs, indeed, the assimilation of water, or its equivalent hydrogen, into nitrogen, is somewhat distinctly intimated. The lungs are, by their natural organization, conformed to a mixture of vital air and nitrogen; and when this natural state is destroyed, their action tends to restore it. Thus, Messrs Allen and Pepys confined a guinea-pig in an atmosphere of vital air, and the residuary atmosphere was found to contain a volume of nitrogen larger than the animal's own body. In another experiment, they confined it in an atmosphere composed of 21 parts vital air, and 79 hydrogen: the result was the same as before, but the appearance of the nitrogen was accompanied with the disappearance of a quantity of the hydrogen. It is never safe to judge of the healthy functions of an organ, by placing it in circumstances where a diseased or unnatural action is demanded; but all experiments are adverse to the opinion, that any quantity of the nitrogen, so abundant in animal bodies, can be derived from the air. The experiments of Dr Edwards even prove, that animals give out more than they inhale, and that chiefly at the fattening time of the year, as if an excess generated from the food eaten, found an exit from the lungs in a manner analogous to carbon. The growth of fishes is sometimes amazingly rapid, while their respiration is very inconsiderable.

These facts, and others afterwards to be mentioned, connected with the voltaic decomposition of ammonia, have induced some chemists to regard nitrogen as a more compound body than oxygen; but under the electric discharge it suffers no more change than the other. Indeed, we should expect that hydrogen and nitrogen are the two gases into which others should be resolved in such a process, rather than that they should suffer change; and perhaps means may yet be discovered for converting oxygen and nitrogen into each other. There seems no reason why an electric shock, which is chiefly transmitted along the radiant medium, should injure either of them. But time, and the sunbeam made to act upon bodies in certain unnatural electrical states sustained during the whole experiment, might probably effect many of those changes which are alluded to; and from many gases, perhaps the same residuary matter might be obtained, consisting of water; or that aëriform body whose symmetry and electrical state are most perfect, and whose aptitude for the aëriform state the greatest, with such an admixture of some other gas as might render the electrical state of the resulting volume perfectly neutral and quiescent, after which, there would be no change, that is, a quantity of nitrogen, with a certain determinate mixture of oxygen—or common air.

Common Air.—The elastic fluid which surrounds us, descending into our lungs during respiration, and producing the sensation of pressure when it blows upon us, is a mixture of nitrogen and vital air, in the proportions of four binate molecules of the former, to one binate molecule of the latter. There are also small quantities of other aëriform bodies present, such as aqueous vapour, and fixed air; but the medium around us is chiefly constituted of the radiant medium or light, of vital air, and nitrogen gas. Were both these gases equally buoyant when mingled, their volumes ought to be, in 100 measures, 80 of nitrogen and 20 of vital air. It appears, however, that the vital air is, when mingled with nitrogen, a little less dense than the other, so that it occupies a larger space. Those admirable men, Cavendish, Davy, Gay-Lussac, Humboldt, Berthollet, and Berzelius, examined air from England, France, Africa, Egypt, and a height equal to the summits of the Himalayas, and constantly found 79 of nitrogen, and 21 of vital air; nor has any observer ever found the quantity of nitrogen to amount to 80 measures in 100. In the nascent state, before the oxygen has acquired its radiant matter, probably the proportions are accurately 4 and 1, and, in general terms, they may be so stated.

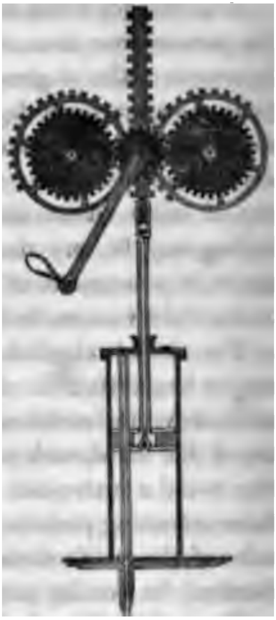
According to the weights of nitrogen and vital air already given, 100 cubic inches of common air ought to weigh $\frac{(29{\cdot}76 \times 79) + (34 \times 21)}{100} = 30.6$. It has commonly been estimated at 30.5, as found by Sir George Shuchburgh and Rice. But

Brande, in most careful experiments, found it, in London, only 30.199; Sir H. Davy found it 30.78; Kirwan, 30.92; and it has been lately announced that Prout finds it 31 grains at least. Thus, the best chemists find that medium in which all others are weighed, to vary nearly a grain in 31, which amounts to the whole weight of 100 inches in two cubic feet. An integrant volume consists of four molecules of nitrogen, and one of vital air, and its atomic weight is (20 × 4) + 22 = 102. To find the atomic weight corresponding to an imaginary particle of air, then, whose volume is constituted of parts equidistant with those of common air and most gases, we may divide this number by five, the number of particles implied in it. This gives 20.4; and when the atomic weight of any aëriform body of equal density, and in the same circumstances as to the radiant medium and specific heat, is divided by this number, its specific gravity is expressed.

The quantity of air around the earth is so great, that every square inch of surface at the level of the sea is pressed by a weight of about 15 lb. which is the weight of an aërial column of this diameter, reaching from the level of the sea to the top of the atmosphere. This elastic medium not only compresses the surfaces of other bodies; but, in consequence of its yielding nature, the superior strata compress the inferior; so that, in all habitable regions, it exists in a state of great constraint and compression. As we ascend, this compressed state gradually diminishes, in a geometrical progression, till, at the top of the atmosphere, the air possesses its true density and symmetry, and is analogous, in its structure, to a crystalline body. The weight of the aërial column is ascertained by a balance of a peculiar kind, which consists of a vertical tube, containing mercury with a Torricellian vacuum at top Into this region the mercury is pressed up as far as the air without is able to effect, and the length of the column, or its weight in a vertical line, is a measure of the existing weight of the air. This length is, on an average, about 29.7, or 30 inches, and the latter is usually assumed as the mean pressure. But it is found not to be uniform at the same level at different times;

thus indicating variations in the weight of the incumbent atmosphere. It is easy to see whence these variations in density of the atmosphere may arise. The condition of the solid strata beneath—the mixture of aqueous vapour,—the intensity of the terrestrial magnetism,—the condition of the earth's surface as to snow, rain, or vegetable covering,—every change must induce a change in the electrical state of the air, and this must produce a corresponding change in the mutual repulsion, or a decrease or increase of density in the particles occupying the region affected. Hence it is always found, that, previous to hurricanes and electric storms, the mercury is lowest, the mutual repulsion being then greatest, and the density and weight of the mass over the barometer least. It may be also, for any thing that can be affirmed to the contrary, that the electrical excitements of the aërial particles may diminish their attractive energy, and, consequently, their gravitation and weight. In both cases, however, an expanded state of the air is the cause of the fall of the barometer. The admixture of aqueous vapour, whose electrical powers have been already described, is the most usual cause of depression in our climates. Hence the mercurial column is our most valuable weather-glass, for, as a storm is the natural process for restoring the electrical equilibrium, when it has been destroyed a storm may be expected; hence the fall of the barometer presages storms.

The variations in density of common air are not confined in the laboratory to those indicated by the oscillations of the barometer. It is possible, by means of the air-pump, to remove all sensible atmospherical pressure from the interior of a vessel, and to reduce the included air almost to the degree of rarity which exists at the top of the atmosphere. There are many forms of this instrument, but none appears to me to possess so many advantages as the following which I have contrived. The kindness of the Reverend George Buist enables me to attach to it a system of wheels invented by him, which is a very beautiful accession to the other means already known for changing a reciprocating into a continued rotatory motion.



The cylinder has an air-tight cover. The piston-rod is hollow, and works in a stuffing box, and the two parts of which the piston usually consists, contain a capsule at the lower extremity of this tube. In this capsule a common conical valve plays in oil. One side of the piston, at the middle of the collars of leather, is drilled to receive a hollow tube, which is a little shorter than the cylinder, and is bevelled into a conical form at both extremities. The conical ends of this tube are received into conformable places in the bottom and top of the cylinder, and the conical hollow at the bottom is the termination of a tube leading from the receiver. In the figure the piston is supposed to be ascending, the air is rushing in from the receiver by the opening between the bottom and the hollow tube, and is filling the vacuum beneath the piston. It is also escaping from above the piston into the air, by the conical valve in the lid, and no otherwise. When the piston descends, the first effect is to press the hollow tube to the bottom; for the friction against the leathers in the piston which act as a stuffing-box to the hollow tube, are quite adequate to this. The air beneath the piston can now escape only by the valve in the piston, and the bore of the piston-rod, into the atmosphere. But all the while that the piston is descending, the air from the receiver is rushing through the hollow tube, and escaping into the vacuum above the piston, to be again expelled during the ascent, by the valve in the cover. Thus one cylinder performs the work of two. The air in the hollow tube suffers equal rarefaction with that in the receiver; and when the piston is at top and bottom, there are no cavities in which air of compressed density can be lodged. The action of the rack-work is apparent on inspection.

The changes which are induced upon bodies, by removing the pressure from them, are very interesting, and their tendency to assume a state of greater rarity is very remarkable. Water boils at a much lower degree of heat than in the air, and many liquids of a volatile nature become permanently aëriform at common temperatures. Water retains a much greater quantity of saline matter without depositing crystals, and solid bodies may be very thoroughly freed from their accidental water, in consequence of its tendency to assume the aëriform state, if the vacuum be kept dry.

The altitude at which the gaseous atmosphere terminates cannot be ascertained. But, if we suppose that it is even 50 miles above the earth's surface, as compared with the diameter of the world, such an altitude would only give an aërial film round a twelve-inch globe less than a line deep, and the dense refracting parts being chiefly confined to within three miles of the earth's surface, would, if viewed from no great distance, be nothing more than a film coincident with the earth's surface, or the limb of its disk. Our atmosphere, then, cannot be regarded as a telescopic feature in our globe, nor is it safe to conclude, that other planetary bodies are destitute of an atmosphere, even though it should be invisible to us.

In considering the natural history of the atmosphere, in relation to its physical phenomena, we must never forget the radiant matter with which it is interlaced. In consequence of this structure, its heat must be chiefly derived from the opaque surface beneath, which intercepts the solar rays, for as they are continuous through the atmosphere, at least, till after reflection, they do not impinge upon the particles of air, so as to warm them. The chief source of the warmth of the air, is therefore contact with the earth's surface; and the heat developed there, is diffused through the mass, according to the manner of liquids, by an ascent of the warmed particles, in consequence of the specific lightness resulting from their expanded and heated state. These ascending particles interfere with the descending ones, and the radiant matter, either from this cause, or because of its own heat, suffers in very hot places some loss of symmetry; hence, over a hot surface, a tremulous transparent movement is observed in the air. These heated aërial particles, as they ascend, do not perhaps become rapidly colder, but the mass of the atmosphere itself must decrease rapidly in temperature or ability to warm other bodies. For the quantity of heat in any volume is proportional to the number of hot particles in that volume; hence, as the air becomes rare, it must become cold. But another cause contributes to the same effect, for the capacity of compressed air for sustaining calorific excitement, must be less than that of rare air. A particle, in a compressed state, if it possess a certain quantity of heat, may be necessitated to part with it, and, consequently, to warm another body, though in an uncompressed state it be able to entertain all that quantity.

That the coldness of the superior strata is great compared with those near the earth's surface, has been long known and justly ascribed to the increased capacity of rare air for heat. The mean temperature has been found to fall off so rapidly, that, at the height of about 15,000 feet even on the equator, water can only exist in the solid form. At the latitude of 45°, the lower confines of this region of perpetual snow terminate at about half this altitude, and approach to the level of the sea towards the poles. Were our globe covered with a shell of snow at its natural elevation, it would possess the form of a sphere drawn out into points at the poles, for the snow-line is represented by a curve, whose ordinates vary rapidly in middle latitudes, but very slowly in polar regions.

The structure of the air in relation to temperature, is the cause of regular and permanent winds, though no doubt winds tend to sustain themselves in many cases, by the electrical development which they occasion when once excited. Their utility in the economy of the world is very great, equalizing the temperature of regions unequally exposed to the sunbeams, aiding the evaporation of water, changing and purifying the air, which stagnates over any region, and facilitating communication between distant lands.

Though, as has been stated, the specific heat of compressed air is less than that of rare air, yet, in all states, aëriform bodies have a great specific heat, and, when they are compressed, there must be a great development of temperature. The air, then, heated where the influence of the sun is greatest, must be very warm, and might be used to warm the polar regions, could it be prevented from parting with its heat during its passage north and south. But if it were carried along the surface of the earth, it is evident, that, for every degree that it changed its latitude in both hemispheres, it would become rapidly colder, and would speedily be assimilated in temperature to the climate through which it was proceeding. That it might be conveyed to great distances in the warmed state, it becomes necessary that it should be removed from the earth's surface which cools it, and be rarified, that its capacity for sustaining its state of heat into which it is thrown at the surface of the earth may be greater.

Now, it has been already shewn, that when air is heated it ascends, and that a quantity of warm air occupies a larger volume than the same quantity of cold air. If, then, we conceive the parallels of latitude to be raised up into walls which reach a little beyond the top of the atmosphere, when it is all equally cold, and the sunbeams then to play upon the Earth, it is evident that the zones of air included between the equatorial walls will, in consequence of their expansion by the greater heat to which they are exposed, be loftier than the polar zones; nor will the case be altered, though we suppose the walls to be perforated beneath, so as to admit of a free lateral communication between the zones of air formerly represented as insulated. All had originally the same weight, and, therefore, they will continue to balance each other, for we need not take into account the actual loss of weight which would be sustained by the *particles*, in consequence of their greater heat diminishing their attractive energy. Suppose, now, that the tops of the walls which confined the different zones in their places were removed, it is evident that, like any other fluid, the equatorial air would flow over on both sides towards the poles. But a column could not shorten, without its weight at the same time lessening, and, consequently, the air from the polar regions, which still retains all its weight, would fall down, and, rushing through the apertures of lateral communication, would cause a north and south wind at the surface of the earth; and thus two vortices, one in each hemisphere, would be established, which would continue as long as the sun shone. The movements would be the same, though there were no such walls as have been imagined to facilitate the conception of the phenomena, nor any other state than that which exists in nature. For the purposes of studying such a vortex in a fluid, produced by a difference of temperature, it is only necessary to light a candle with a small wick, and of a very fluid material, such as spermaceti, and, when the matter surrounding the wick is melted, the movement will begin, and be sustained in a very beautiful manner. It is similar to that which has been assigned to an oblate or electro-negative molecule, Fig. 19.

The vortex thus anticipated is most beautifully exhibited on the surface of our globe, modified according to all the conditions of the physical structure of its surface. The height of the atmosphere, where dense enough to entertain currents, is so inconsiderable, compared with the distance between the equator and the poles, that this wind has its polar confines in latitudes much lower than the Arctic Regions. For it is merely a movement to restore equilibrium, and all such are effected in nature according to the principle of least action. It is therefore the disposition of the vortex to contract and be contained in as narrow a zone as possible. There is another circumstance, too, which removes the region between the two vortices from the terrestrial equator to another zone. This is the excess of land in the northern hemisphere. The neutral region must evidently be the equator of greatest temperature, and this line is considerably on the north of the terrestrial equator. Neither are the directions of the currents due north and south, for this could only take place if the globe were at rest, or all its parts moving with equal velocity, neither of which is true.

In consequence of the greater velocity of the equatorial regions, the currents coming up with a slower movement from the poles resist the earth's movement towards the east, and hence act upon the earth's surface as winds blowing from the north-east and south-east. Their regular institution is to be observed where the surface has an uniform structure at about the latitude of 30°, and the region of quiescence or neutrality lies chiefly between the third and fifth degree of north latitude. But the perpetual movement of the air in a direction pretty uniform at the surface of the earth, is not the only evidence afforded of the existence of this atmospherical vortex. In several regions within the zone of the trade-winds, clouds at great elevations are observed to move uniformly to windward, indicative of a current where they are in an opposite direction to that at the surface of the earth; and dust ejected from volcanoes has been carried 100 miles against the wind. Nay, at the top of the Peak of Teneriffe, it is said that the supernal current may be entered.

In middle latitudes beyond the external confines of the trade-winds, are variable winds modified by their proximity to the regular vortex; and, in the polar regions, the winds are quite partial and variable, as in the region of the equator of temperature.

The atmosphere is agitated and set in motion by other causes, however, than a simple change of temperature. Many local winds, and especially such as are of a violent character, are more usually determined by that cause of dilatation which depresses the barometer, electrical excitement. The institution of local vortices to restore the equilibrium in such cases, is generally very readily observed by the movement of the clouds in a contrary direction to what the wind is blowing at the surface of the earth.

The unequal density of the atmosphere likewise gives rise to some very interesting optical phenomena. The course of a ray of light from any heavenly body, is necessarily not straight, but bent towards the perpendicular more or less, according as it traverses a greater or less quantity of air, varying rapidly in density. As the mind believes a body to be in the direction of the last part of a ray of light which enters it, this atmospherical refraction elevates the apparent altitude of all the heavenly bodies by a quantity which, at the horizon where it is greatest, is equal to about 32′, or the diameter of the sun or moon. Hence the disks of these luminaries are sometimes wholly visible when, geometrically regarded, they are set, or have not yet surmounted the horizon; and hence, in Paris in 1750, both the sun and moon were seen above the horizon at the time of a lunar eclipse, which, without the elevation occasioned by atmospherical refraction, had been impossible. The rapid increase of this refraction is also sometimes adequate to distort the forms of the sun and moon in a very sensible manner, by elevating the lower limb more than the upper, and making them seem gibbous on their lower region. This may be often observed, when the sun begins to descend among the smoke of London, that part of the disk which is most fully immersed being flattened, as if he met with actual resistance in penetrating the carbonaceous medium. The same inflections of the rays of light give rise in certain states of the air, to the very singular phenomena of mirage and Fata Morgana, in which objects are elevated, repeated, inverted, and distorted often in a very beautiful or fantastical manner.

The light of the rainbow and of the azure is always completely singled, the edges in the former being parallel to the circumference of the cone, of which the arch is the base, and the eye the apex; in the latter, in two planes in a direction opposite the sun, and especially at great elevations, the light is singled with the edges horizontal, on the right and left of the sun it is singled with the edges vertical, in a direction distant 74° from the sun's centre. This is the angle which ought to result if the singling particle were water, with its axis directed towards the sun; and this, it has been justly remarked, affords a very strong evidence that the only aëriform body in the atmosphere which reflects light or becomes visible, is the aqueous vapour. The particle of nitrogen has not opposite faces or edges on the polar aspects in the same plane. But if, as in the case of the aqueous particle, we produce an edge and draw a perpendicular to the corresponding face, the one forms with the axis an angle of 60° and the other 35° 15′ 52″, the resultant of which gives 47° 37′ 56″. No other can be obtained from vital air. We found that, in this way, the singling angle of water was obtained; and the singling angle of common air observed is said to be 45° or 47°.

Nitric Acid, Aquafortis.—In what combinations nitrogen exists in animal bodies has not yet been discovered. In the atmosphere, when traversed by the electric discharge, or resident over certain disposing substances, the elements of the air are apt to condense in small quantities, and there results a chemical compound of oxygen with a binate molecule of nitrogen (or atmospherical nitrogen), which is the only one known to exist. All the other bodies commonly recognized as such seem to be compounds, not of nitrogen in molecules, but in particles.

Nitric acid is developed somewhat abundantly in many regions of the earth where matter exists beside it, which is either potash, or easily convertible into this alkali; for potash is one of the few bases with which the nitric acid can form a solid or permanent body. From the very interesting salt which results, named Nitre, all the nitric acid of chemistry and the arts is produced. Its direct development, by treating the air with electric discharges, is a very laborious and tedious process, requiring such men as Cavendish.

It is evident that the number of particles of oxygen proper to a molecule of nitrogen is one, two, or five. The last number gives rise to the most perfect form, and this is accordingly the number which chemists have found in nitric acid.—(Fig. 41.) Its atomic weight is 70, composed of 50 oxygen, + 20 nitrogen, which is almost exactly the mean between the determination of Berthollet and those more commonly received. It is one of those forms that are calculated for permanent existence only in a state of union. Unless there be some other body attached to it, having five prominent parts of opposite electrical affections, so as at once to respond to its symmetry, and neutralize its excess of negative electricity, nitric acid cannot be expected to be very permanent. The five particles of oxygen are very much within the sphere of mutual repulsion, and their poles quite naked to the access of radiant matter and every combustible body. Hence we may readily believe that it is only the very favourable position which they may assume, and the great symmetry of the resultant form, that retains them in unison. There is a want of symmetry, however, on opposite sides of the equator, an accumulation of matter towards one pole. Hence a powerful affinity is exerted towards some neutral body, such as water, to balance the excess.

Nitric acid cannot be preserved free from water; and the just number of aqueous particles necessary to hydrate one of acid is evidently five. Like the oxygen, it will be accommodated around the other pole, which has five edges. Now, it was long ago observed by Bergmann, that weaker and stronger acids are reduced by boiling to the specific gravity of 1.42; and that acid of this strength was distinguished from all others by possessing an individuality, in virtue of which it could be distilled over unchanged, requiring a very high temperature to cause it boil. The proportions of acid and water, in liquid acid of this density, Mr Dalton states at 54.4 dry acid, and 45.6 water per cent., or 70 dry acid, and 58.7 water, which is as nearly the ratio of one particle of acid and five of water as could be wished.

Nitric acid is very easily decomposed. The action of the sunbeam destroys it, separating its oxygen, and giving rise to vital air, or compounds of oxygen and nitrogen, and along with this decomposition there is a development of colour. Henry, in his very elegant Elements of Chemistry, says, "It becomes coloured by exposure to the sun's light, passing first to a straw colour, and then to a deep orange. This effect is produced by the union of the light of the sun with oxygen, in consequence of which the proportion of the acidifying principle to the nitrogen is diminished." Most combustible bodies decompose nitric acid; and many inflammable substances, such as charcoal or essential oils, unite with violent combustion. Its taste is intensely sour. It stains the skin of a permanent yellow colour, corrodes the animal tissue, and, during dilution with water, changes colour, assuming different tints successively between pale yellow and bluish green, and disengaging at the same time suffocating fumes.

The properties of nitrogen in particles are not known, as, when nascent in the free state, it constantly unites in binate molecules, constituting nitrogen gas. The substances which result from the union of nitrogen in particles and oxygen are very interesting; and it is evident that there may be several of these. None possesses more curious properties than

Intoxicating Gas.—When nitrogen in particles and oxygen are presented to each other in the nascent state, in the proportions of two particles of the former to one of the latter, an invisible gas ascends, which has been called Nitrous Oxide, Dephlogisticated or Nitrous Air, or Intoxicating Gas. It is usually procured by exposing to the proper temperature an easily decomposable salt, named Nitrum flammans, or nitrate of ammonia, which consists of a particle of each of its constituents. A particle of ammonia, as will be afterwards shewn, when decomposed into gas, gives rise to two of nitrogen and three of hydrogen. A particle of nitric acid gives rise to two of nitrogen and five of oxygen. Three of the five particles of oxygen derived from the acid uniting with the three particles of hydrogen derived from the ammonia, form three of water; and there remain four of nitrogen to unite with two of oxygen, a particle of nitrogen occupying both the poles of a particle of oxygen. The resultant molecule has concave pores like oxygen itself; each particle, therefore, on its emergence into the radiant medium, receives an atom, so that there results a very beautiful form (Fig. 42.) whose atomic weight is 32 (10 oxygen + 20, azote + 2 atoms).

The atomic refractive power of this body is nearly the same as that of nitrogen, and its atomic specific heat appears from the tables to be less. We may therefore expect it to be rather heavier than the weight of its elements, estimated separately. These give 48 grains (29.67 nitrogen + $^{55}/_{3}$ oxygen + 3 atoms), while its atomic weight, compared with that of common air, makes it 48.6. Sir H. Davy states, that 100 inches weigh between 48 and 49 grains. It may sometimes, however, be prepared so as not to demand the atoms, in which case its weight, as estimated from its elements, would be 45 grains, which was the weight of that prepared by Colin.

Gases of this nature are somewhat readily decomposed, and their structure may at the same time be detected. Thus, if a quantity of hydrogen or carbon be mingled in this gas, and fire or the electric spark applied, the oxygen leaves the azote to unite with the combustible. Now, it is found by experiment that this gas, for engaging all its oxygen as water, requires a volume of hydrogen equal to its own; and it is evident that this is just the quantity necessary, according to the view now advanced, and that there will result a number of binate molecules of nitrogen, equal to those of the gas destroyed, that is, an equal volume of nitrogen. It may be regarded as composed of a volume of binate nitrogen, and an equal number of particles of oxygen (that is, half a volume of vital air) occupying one volume. Its structure is also made evident by the following experiment: Carbon, where it unites with oxygen to form fixed air, indicates the volume of oxygen present, for there is no change in bulk during the transition of vital into fixed air. Now, it is found, in reference to intoxicating gas, that when it is resolved by combustion into nitrogen and fixed air, one volume is expanded into one volume of nitrogen and half a volume of fixed air, which indicates half a volume of vital air.

Intoxicating gas is invisible, has a faint agreeable odour, and a sweetish taste. It supports combustion with much vividness. There is evidently twice as much oxygen present in a given volume as in the same bulk of common air, and probably the azote is as easily displaced in this case as the atoms in vital air.

Its most interesting property, however, is, that it may be breathed for some minutes in a state of purity; and, instead of suffocating, or inducing spasms in the glottis, generally producing a very vivid intoxication. It is, as well as vital air, evidently able to impart radiant matter to the system, but it is not equally well fitted for relieving the system of carbon. Hence, by breathing it, radiant matter is given into the system, while the carbon is detained in it. It appears, from the experiments of Prout, that, in states of intoxication, carbon is not given out from the blood in its usual quantities, while the powerful action of the lungs, in such a state of the vital functions, implies that vital air descends even in increased quantities. The circumstances in breathing intoxicating gas, then, are the same as when breathing common air during a state of inebriation; but, in this case, the intoxication is without that sickness and ill-health which arises from the absorption into the system of injurious substances. This gas is not known to be developed in nature; and, though it were, its detection in the atmosphere would be extremely different.

Nitrous Gas.—When nitric acid is decomposed by the action of some metals, as when it is poured on copper, a very simple gas ascends, composed of a particle of nitrogen, united to one of oxygen (Fig. 43). It has been called Nitric Oxide, Deutoxide of Nitrogen, or Nitrous Gas. When it is completely charged with radiant matter, probably there is an atom on each pole. Its atomic weight is then 22. When charged with two atoms of radiant matter, 100 inches will weigh 33.4 grains; when with one, which is probably its most legitimate state, 31.9; and without any, 30.4. By Sir H. Davy, it has been stated at 33.8 and 32 grains; by Thomson, 31.77; and by Berzelius and Dulong at 30.53.

When decomposed, it must evidently yield equal volumes of nitrogen and vital air, and that without any expansion, for the analysis is merely a resolution of the whole into a number of binate molecules of the two gases, equal to that of the particles of the nitrous gas decomposed. Or, when the oxygen is resolved into water, there must evidently remain half the original volume of nitrogen. If, again, it be exposed to such bodies as the sulphites, which do not require much oxygen, but have an urgent demand for what they want, every particle of azote, abandoned by its oxygen, may unite with the contiguous particle of nitrous gas yet undecomposed, and constitute one of intoxicating gas, which, in consequence of its oxygen being locked up, may escape decomposition. When this decomposition is effected in a perfect manner, it is evident that one volume of nitrous gas must give rise to half a volume of intoxicating gas; and this is found by experiment. The most interesting feature of this gas is its action with vital air in the atmosphere which contains it. When by itself, it is colourless, and but slightly absorbable by water; but when mingled with vital air, a deep orange-coloured gas appears, which rapidly settles down in the water, rendering it acid, and communicating its colour to it. Hence nitrous gas is often used in the eudiometer to detect the presence of vital air. The substance which results from the union is

Nitrous Acid.—Experiments prove that half a volume of vital air is necessary to change one of nitrous gas into nitrous acid. This might be expected, if we consider that, by such an accession, a more highly symmetrical particle results than can be otherwise produced, every particle of nitrous gas being served with one of oxygen, on the exposed pole of the nitrogen (Fig. 44). In the aëriform state, it will receive radiant matter on its poles, in which case its atomic weight will be 32. The natural state of nitrous acid is in union with water, which, when it has absorbed the acid fumes, becomes liquid, if previously in a solid state, disengages suffocating fumes, and displays a yellow colour, similar to that of nitric acid degenerating when exposed to light.

Hyponitrous Acid.—In particular states of combination, these two substances, nitrous gas and nitrous acid, exist together, constituting what has been called Hyponitrous Acid. It is constituted of two particles of nitrous gas, with a particle of oxygen between them (Fig. 45). When disengaged from union, it separates into nitrous gas and nitrous acid.

Thus, from the destruction of nitric acid, four distinct bodies can be produced, which are compounds of nitrogen in particles with oxygen. These five seem to exhaust the possible combinations of the two bodies. Their composition may be thus stated—

		Particles.				Volumes or Parts.		
	Atomic Weight.	Nitrogen.		Oxygen.		Nitrogen.		Oxygen.
Nitric Acid,	70	2	+	5	or	100	+	250
Nitrous Acid,	30	1	+	2		100	+	200
Hyponitrous Acid,	50	2	+	3		100	+	150
Nitrous Gas,	20	1	+	1		100	+	100
Intoxicating Gas,	32	2	+	1		100	+	50

SULPHUR.

Hydrogen gives rise to water, oxygen, and nitrogen, chiefly by the combined demands of electricity and symmetry. But its particles are capable of other forms in which they are united crystallographically, or by their terminal edges, the pole of one being applied to the equator of another, in which case, the energy of cohesion is a maximum, and the constitution more independent of electrical state. For generating a particle of water, six of hydrogen are simultaneously required; any smaller number, when presented to each other, will often unite into a spiral fibre, the particles being united by terminal edges. Five particles thus constituting an axis, by uniting its opposite poles, again developes a particle of oxygen, and in this way it may be frequently generated in nature. But a mass of hydrogen in this fibrous state, where five particles are permitted to unite, will, in all ordinary circumstances, arrange themselves into a highly symmetrical bipyramid, in which every other particle coheres by three, and those on the axis by four angles, as in Fig. 46. There are no faces suppressed, except those which form the equator of the hydrogens. The form which results, is therefore one of very great permanency and stability, in which respect it may only be surpassed by iron, silicon, potassium, and such other forms as possess great symmetry, and contain no faces whatever, opposed or suppressed. This constitutes a particle of sulphur. Its atomic weight is 10, which is the half of that commonly assigned. 100 inches in the state of vapour, and in the same circumstances as common air, would weigh about 15 grains. Its capacity for heat must be very great, as its poles are so well suited for vibration. It agrees with water and oxygen in possessing an exposed centre; and it therefore affords access to a region which is always at the zero of temperature; but the forms which can find admittance are limited, as in the case of water. Like water, sulphur is at once electro-positive and electro-negative, in a high degree. There are three negative regions in every particle.

We should be disposed to infer, that its repulsive fluid must possess two series of polarizing axes, one connected with the terminal particle of hydrogen, and the other with the equatorial particles. Viewing a particle of sulphur in the direction of the axis, there are twelve faces whose perpendiculars form similar angles with the central and lateral axes of 70° 31′ 44″; and there are three terminal edges, forming with the axis an angle of 35° 15′ 52″. If we suppose the resultant of these to give the angle which the resultant polarizing axes form with the axis of the particle, it is $\frac{(12 \times 70^\circ\, 31'\, 44'') + (3 \times 35^\circ\, 15'\, 62'')}{12 \qquad + 3} =$ 63° 28′ 36″. This agrees well enough with the polarizing angle, ascertained by observation, which is stated at 64° 10′, that deduced from the index of refraction being 63° 45′. But it will no doubt vary somewhat in different azimuths in a crystal so strongly doubly refractive as sulphur.

The particles of sulphur must be capable of giving rise to crystallizing molecules of two sorts, each implicating eight particles. That which arises simply from the force of crystallization, consists of two parts applied face to face, each composed of four particles united by two edges, so as to develope a rhomboidal plate; and two such rhomboidal plates constitute a symmetrical molecule. These uniting again produce a rhomboidal plate of similar dimensions, which may become the equator of a scalene four-sided bipyramid, such as that in which sulphur occurs crystallized in nature, the resultant angles depending on the balance between those which the particles, in consequence of form, would affect, and those which the laws of symmetry and polarized action would determine, if the particles of sulphur possessed a common tessular form.

But when particles of sulphur are free to move among each other, as in a state of fusion, the hot and positive poles of three particles will naturally seek the cold and negative centre of a fourth; and thus another molecule (as in Fig. 49, in which there are two additional particles of hydrogen, one on each pole, at present to be disregarded) will result, composed, in like manner, of four particles, but in a very different position; and two such will constitute a symmetrical molecule, which must give rise to crystalline forms, very different from those evolved by the former. Now, it is ascertained that sulphur, when crystallized from fusion, assumes a form very different from native sulphur, and such as cannot be reduced to the same fundamental form. The atomic weight of this quaternate molecule is 40. It occurs very frequently in the combinations of sulphur, and corresponds to the atomic weight of sulphur, as lately assigned by Berzelius.

Sulphur, as might be expected from its origin, is a very abundant production of nature. It forms, in an uncombined state, immense beds in volcanic districts; nor is it confined to these, but is met with both in primitive and secondary rocks, not volcanic, especially along with gypsum and rock salt. In a state of union, it is met with abundantly in pyritic minerals, in gypsum, heavy spar, and others. United to iron and copper, it forms beautiful minerals, which retain its colour, but possess a metallic lustre. In metals of heavier particles, its place seems to be occupied by arsenic, a substance whose nature is evidently related to sulphur.

In its perfect form, sulphur is a yellow, or sometimes limpid crystalline body, very easily frangible, scarcely possessing a regular cleavage. It fuses at a temperature somewhat above the boiling point of water, and soon after becomes highly liquid. At a higher temperature the poles of some particles begin to seek the cold centres of others. The mass increases in density, becomes viscid and tenacious, and changes from a yellow colour to one of a copper red. At about the boiling point of mercury, sulphur ascends in coloured vapour in quaternate molecules or molecules of fusion, but at this degree of heat it is combustible in the atmosphere. The fumes generated by this combustion are very suffocating and peculiar. But its union with oxygen renders it impossible to discover the actual odour of sulphur vapour. Judging from its odour in the gaseous state, when united to hydrogen, we should infer that it is very fetid, and probably like that of garlic or horse-radish. When the vapour is prevented from burning, it collects in the cold part of the chimney as a beautiful yellow gritty powder of a bright yellow colour, with little taste and smell, but of a very penetrating nature, and apparently not suffering decomposition in the animal system.

When sulphur is introduced into the voltaic focus, it is slowly resolved into hydrogen, which takes up a part of what remains undecomposed, and thus relieves it from the voltaic energy. The quantity, however, which has as yet been decomposed in this way is very inconsiderable; nor is it impossible but the hydrogen, which is obtained from sulphur in these circumstances, may only be particles accidentally present. When heated along with carbon, a great quantity of hydrogen appears, which cannot be otherwise accounted for than by the decomposition of the sulphur. From an investigation of their habitudes together, Berthollet concludes, "On ne peut douter d'apres cela qu'il n'y ait de l'hydrogene dans le soufre. Cet hydrogene a du contribuer pour plus qu'on ne le concluroit de ces dernières expériences seulement, au volume des gaz dégagés lorsque le soufre porté en grand quantité sur le charbon, le volatise à l'aide d'une haute température. Le gaz qui se developpe alors est dû à l'action réciproque du soufre et du charbon, et à celle qu'ils exercent l'un et l'autre sur l'hydrogène combiné dans chacun deux; Mais la quantité de soufre qui devient nècessaire pour que cette combinaison se forme autorise à conclure en supposant que le charbon contient encore de l'hydrogène que c'est néanmoins le soufre qui en donne la plus grande partie."*

Sulphureous Acid. Fumes of Sulphur.—When sulphur is rubbed, it acquires a peculiar smell, but when heated nearly to the point of inflammation, very suffocating fumes ascend, and when it burns, they are generated in vast quantities. They are developed in volcanic regions, and where coal, containing pyritic matter, is consumed. They are very injurious to the lungs, and to the vegetable organization: it has been ascertained, that a mixture in the air, so slight as not even to affect the senses, curls the leaves and injures the health of plants. Hence, one cause of the inferiority of vegetation in smoky districts, where coal is burned.

The same fumes are generated when sulphur is burned in vital air; and there can be no doubt that it is a case of simple combustion, in which every atom of the radiant matter of the vital air is replaced by a particle of sulphur. The atomic weight of a particle (Fig. 47.) is 20, or half that assigned by Thomson or Dalton. It evidently possesses the structure which discharges colours already described, and this property it is found to possess, though, in consequence of its acid nature, it first reddens them. The particles of oxygen in the sulphureous gas may perhaps remain in the same positions as in vital air, with sulphureous, instead of radiant poles. In which case, 100 inches would, in their nascent state, weigh 31 + 30 grains; but sulphur is such a form, that, immediately on coming into the radiant medium, it can only be expected that every particle shall become charged with atoms to fill up and relieve the excessively negative-electrical state of its equator, the limit of which is six atoms to every binate molecule of the sulphureous gas. This would raise its weight from 60 to 70 grains. If, again, we suppose that the sulphur is arranged in quaternate molecules, or molecules of fusion, constituting aërial molecules, which, like others of similar magnitude, occupy a double volume, the central particle of sulphur in every molecule will be free from atoms, its demand for matter in the hollows of its equator being satisfied by the three surrounding particles of sulphur. This will reduce the weight of 100 inches 2.2 grains, and it will therefore be 67.8 grains; and this will be about that quantity found by the balance, as its atomic refractive power is the same as that of common air. Sir H. Davy, Thomson, and Thenard, found it about 68 grains.

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* Memoires d'Arcueil, t. i. p. 331.

Molecules of this form are extremely impatient of the gaseous state. The fumes of phosphorus, whose structure we shall find in the highest degree analogous, cannot be prevented from aggregating in flocculi, which are precipitated, and those of sulphur can only be sustained in vessels composed of a substance for which they have no affinity, when no water is present, and when the medium is not intensely cold.

This gas may be reduced into a liquid state by being passed through a very cold tube, or by being pressed by two atmospheres. Water absorbs it very readily, and remains for some time a fuming liquor, from which the fumes may, for some time, be recovered in a free state. But when the access of more oxygen, or vital air, has been afforded, the water loses its sulphureous odour, becomes intensely sour, and may be raised to the temperature of 550° Fahr., without giving off any other vapour than pure steam.

Oil of Vitriol.—Sulphuric Acid.—The sulphur, water and oxygen have now arranged themselves in a form of great symmetry and stability. Two particles of sulphureous acid having inserted themselves in the two poles of a particle of water to which they are conformable, the two particles of oxygen, aided by a third derived from the atmosphere, have moved from the poles to the equator, and thus three particles of oxygen, the number demanded by a particle of water, are arranged on the alternate segments of its equator, while the particles of sulphur remain inserted, one in each pole, forming an axis to the molecule, as in Fig. 48.

The atomic weight of a particle of oil of vitriol in those cases where the sulphur still retains the radiant matter, is 68.

1 water,	12
2 sulphur,	20
6 atoms,	6
3 oxygen,	30
	68

In cases where it is free from atoms, its weight is 62. Now, Sir H. Davy assigns the constitution of oil of vitriol to be 30 sulphur, 45 oxygen, and 17 water; and 30, 45, and 18 are in the same ratio as 20, 30, and 12, the proportions just assigned. Oil of vitriol is, at ordinary temperatures, a liquid, having the aspect as to fluidity of oil; but it differs remarkably in being very heavy, in possessing a very low refractive power, in mixing with water in all proportions, in dissolving and corroding the skin, and in charring vegetable substances. It boils between the melting point of tin and lead; and both stronger and weaker acids are reduced by boiling to the same degree. In this there is no water present except that implied in its constitution, and it corresponds to the hydronitric acid formerly described. It is frozen with extreme difficulty. But at that degree of dilution, when one particle of water is supplied to every particle of oil of vitriol, it is evident that it may very readily assume the spicular form, a series of particles being united by the concave poles of the particles of water between each, which serve as a connecting box. In consequence of this insertion of the poles of the sulphur into the poles of the water, condensation ensues during dilution, and there is a loss of the specific heat of these poles of the sulphur, and much heat is given out.

A binate hydrated molecule, consisting of one particle of oil of vitriol with one of water on each pole, is the most symmetrical and dense state in which the acid can exist, and, consequently, at this degree of dilution the condensation ought to be greatest, the ratio of acid to water being 62 or 65 to 24. Now, Dr Ure found the greatest condensation when the ratio of oil of vitriol to water was 73 to 27, which are in the ratio of 65 to 24, or 62 to 23.

The conformable character of the particle of oil of vitriol to water, and its deficiency in quiescence of electrical state, are indicated by the avidity with which it unites to water, desiccating, in a remarkable manner, the atmosphere around it, and becoming weaker by absorbing the vapour. It decomposes vegetable substances, seeming, in many instances, to resolve them into water and charcoal; hence when straws, or other vegetable bodies, fall into oil of vitriol, the liquid becomes brown and discoloured by the mechanical suspension of the disengaged charcoal. In some cases, it appears also that oil of vitriol is discoloured by the generation of a little selenium, as has been suggested by Dr Thomson, and since ascertained.

This powerful acid is a production of volcanic regions, existing both in a liquid state and that of vapour: it also occurs united to metallic oxides, constituting salts. For the purposes of chemistry and the arts, it is usually prepared by burning sulphur with nitre over water, or by expelling it from green vitriol, a salt of iron in which oil of vitriol exists abundantly. When this salt is distilled at a strong heat, a liquid of a dark colour and oily consistence comes over, which, unlike oil of vitriol, boils at a very low temperature, and gives off fumes at all temperatures. It consists of oil of vitriol and anhydrous sulphuric acid. The latter is a form in which the oxygen and sulphur are in the same proportion as in oil of vitriol, but in such a state of impatience to become oil of vitriol, that, when a little of it is dropt in water, it hisses like a red-hot iron. When this fuming liquor is distilled, the anhydrous acid comes over, and, by cooling successfully, it may be condensed into a solid white silky asbestiform body. It often happens, that oil of vitriol, when offered union with certain bodies, parts with its water, which is replaced by the base, and then its atomic weight is that of the anhydrous acid, 50 or 53, or, perhaps in some cases, even 56.*

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* The atomic weight of anhydrous sulphuric acid is generally stated at 50, and that of oil of vitriol at 61.25, and, disregarding the accidental

Hyposulphuric Acid.—Sulphureous acid and oil of vitriol are the substances which naturally result from the union of oxygen and sulphur. By the ingenuity of Welter and Gay-Lussac, these two substances have also been made to unite with each other, so that the two naked poles of the oil of vitriol are covered by two particles of sulphureous acid. The beautiful form which results has obtained the name of Hyposulphuric Acid. It has a sour taste, reddens vegetable colours, and unites with bases forming soluble salts. The application of heat drives off the sulphureous acid and leaves oil of vitriol. Its atomic weight is 102, (sulphur 40, oxygen 50, water 12). The same ratio of sulphur and oxygen would, however, result, if a quaternate molecule of the former had a particle of oxygen on all its poles. This would be an anhydrous hyposulphuric acid, whose atomic weight would be 90, as commonly assigned.

The Hyposulphuric Acids.—Besides these there are probably three other acids of sulphur that have been prepared in the laboratory. Two of these possess very simple structures, and have both been described under the name of hyposulphureous acids.

1. *Hyposulphureous Acid of M. Gay-Lussac and Mr Herschel.*—By deoxidizing every other particle in a quantity of sulphureous acid, or by supplying every one with an additional particle of sulphur, an acid results in which the ratio of sulphur and oxygen is 2 to 1. There are two forms in which this ratio is compatible with a symmetrical existence. The particle of oxygen may have one of sulphur in each pole, or a quaternate molecule of sulphur may have one of oxygen on each pole of the central axis. In the former case its atomic weight is 30, in the latter 60. The progress of development appears to be, that the former changes into the latter,

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atoms to which both are incident, 50 and 62 are the true weights; but it will only be by subsequent experiments that we shall learn how far we can count upon an uniform atomic weight.

the limit of which is one particle of oxygen to a quaternate molecule of sulphur. This is the

2. *Hyposulphureous Acid of Dr Thomson*, Phil. Trans. 1827.—Its constitution is more analogous to other acids than either of the former. It is nearly isamorphous with the other, and, like it, forms soluble salts with bases, which with sulphuric acid form salts quite insoluble. They are of little interest, and the salts of the two acids seem to pass into each other. Its atomic weight is 50, composed of a quaternate molecule of sulphur, 40 + 1 particle of oxygen, 10.

Six acidous compounds of oxygen and sulphur are possible, and were we to assume one analogous to the deutoxide of hydrogen, seven might exist. Such forms, however, are extremely rare.

	Weight.	Sulphur.		Oxygen.		Sulphur.		Oxygen.
Sulphuric acid,	50	2	+	3	=	100	+	150
Hyposulphuric acid,	90	4	+	5	=	100	+	125
Sulphureous acid,	20	1	+	1	=	100	+	100
	70	4	+	3	=	100	+	75
Hyposulph. acid (Gay-Lussac,)	60	4	+	2	=	100	+	50
Do. do. (Thomson, 1827,)	60	4	+	1	=	100	+	25

Sulphuretted Hydrogen.—Sulphur is highly negative in relation to hydrogen; hence it enters readily into union with it. The sulphuretted hydrogen which most naturally results, is a very fetid and poisonous body, sometimes naturally developed in certain springs, swamps, and volcanic regions, and during the decomposition of animal bodies which contain sulphur. It may also be procured by the action of water upon the sulphuret of a metal. The pure metal having a greater affinity for oxygen than sulphur, decomposes the water, attaches the oxygen, discharging the sulphur which the hydrogen engages, and sulphuretted hydrogen is set free. There is a mutual affinity to aid the decomposition. Sulphuretted hydrogen may also be developed by subliming sulphur in hydrogen gas, in which case it is remarked that, unless the process be continued too long, there is no change of volume, but the weight of 100 inches, instead of being between two and three grains, is now almost 36. These facts indicate that the ratio of the sulphur and hydrogen in the constitution of the gas, is that of two particles of the former to one of the latter. They may be arranged in so many different ways, that it is difficult to satisfy one's self as to the form which the body in the aëriform state will assume. In entering into union, it seems probable that the form will vary according to that with which it combines. Upon the whole, we may regard the most characteristic state of sulphuretted hydrogen as that in which a quaternate molecule of sulphur has a particle of hydrogen on each extremity of the axis, (Fig. 49). This gives a structure analogous to the hydracids, and one in which the oxygen in one of the hyposulphureous, is replaced by hydrogen. Its atomic weight may be 22 or 44 according to circumstances.

The atomic weight of that in which the quaternate molecule is involved is 44, neglecting the radiant matter with which it will become charged in the gaseous state. As we shall afterwards see, such large molecules in which hydrogen is on the poles, are, in the aëriform state, only half as dense as the gases which have yet been noticed; that is, in any volume such as a cubic inch, there are only half the number of particles. The refractive power and magnitude of this body, and its liability to be charged by the radiant matter, are so great, that experiment is the best guide to its specific gravity*.

This substance, in the gaseous state, may be decomposed by combustion with oxygen; and to convert it into water and fumes of sulphur, every particle will evidently require six of

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* Perhaps it may be thus estimated,

Four volumes of sulphur vapour, - -	60.
Nine atoms, - - -	13.5
Two volumes of hydrogen, - -	4.2
	77.7 grs.

There are nine concave poles in every quaternate molecule for the reception of the radiant matter. But 77.7 are the weight of as many particles as are contained in 200 inches of the common gases, and the half of this, or 38.8, would be the weight of 100 inches of sulphuretted hydrogen, on the supposition that this included radiant matter is as dense as in common air. But the gases' action upon light is very great, and the weight indicated by the balance will be less than this. One hundred inches have been found to weigh about 36 grains.

oxygen, or three molecules of vital air, that is 1½ times its own volume, for the molecules of vital air are doubly dense compared with these of sulphuretted hydrogen. The result is water and a volume of sulphureous acid equal to that of the fetid gas consumed. By other means the sulphur may be thrown down, upon which the hydrogen remains occupying the same volume as that of the gas decomposed, two particles of hydrogen being afforded by each particle of the fetid gas.

This inflammable body possesses the properties of an acid, reddening colours, and uniting with bases so as to give rise to crystalline salts. Like all the other saline bodies into which a quaternate molecule of sulphur enters, they are soluble and easily decomposed.

Sulphuretted hydrogen is very poisonous. In the stomach, indeed, it is rapidly decomposed; but, when absorbed by the skin, it proves so fatal that an animal is speedily destroyed when enclosed in an atmosphere composed of it, though the creature is permitted to breathe good air. When made to breathe air containing $\frac{1}{1500}$th part of its volume of this gas, a small bird died.

It is combustible, giving rise to sulphureous fumes. It unites very readily with water, and settles on metals, and earthy and alkaline bases, giving rise to variously coloured sulphurets, hydrosulphurets, and hydroguretted sulphurets. Hence it tarnishes metals and injures metallic colours.

Supersulphuretted Hydrogen.—Another compound of sulphur and hydrogen has been distinctly recognized, which appears to possess the same structure as the former, but with a particle of hydrogen on one pole only. It now wants buoyancy to assume the gaseous state, and, though very volatile, exists at ordinary temperatures as a viscid fetid liquor. Like the former, it unites with bases, and the compounds resulting have a greenish-yellow colour, a very bitter taste, and offensive smell. They are speedily decomposed by the action of the air, and the hydracid changed into the corresponding oxygenous acid. The atomic weight of this substance is 42. Its salts are named Hydroguretted Sulphurets, and it has itself been named Bisulphuretted Hydrogen. From its avidity for oxygen, it has been used in eudiometry.

Thus, sulphur forms with hydrogen two acid bodies; while with oxygen it forms four at least, distinct from each other. But the number of compounds of sulphur and hydrogen may be much greater; and the state of the matter is very accurately expressed by Berthollet, in the result of his experiments on the Alcohol of Sulphur of Lampadius. "Il (le soufre) forme avec lui (l'hydrogene) des combinaisons donc les proportions varient, et qui selon les circonstances prennent la forme de fluids elastiques, de liquides, ou de solides." —(*Memoirs d'Arcueil*, t. i. p. 332.)

SELENIUM.

Berzelius discovered, among the fæces left by the combustion of impure sulphur, derived from iron pyrites, at Fahlun, in Sweden, a dark coloured matter, which, when burned, emitted a smell like that of horse-radish. This wonderful chemist subjected it to his analysis, and in his laboratory it soon confessed its nature. It has been found by Stromeyer in the fuming oil of vitriol of Nordhausen, in which it is probably generated; and it has also been discovered in small quantities, in union with sulphur, among the volcanic products of the Lipari Isles. There it acts the same part along with the atomically heavy metals, such as lead, cobalt, silver, mercury, that sulphur does with the light. It has also been detected in the Hartz Mountains and elsewhere. All the circumstances of its history indicate its affinity to sulphur. At the boiling point of water it agrees with sulphur at double that degree of heat, being a soft tenacious substance, of a red colour when viewed by transmitted light. At a temperature somewhat above this, it becomes quite fluid; a little above the boiling point of sulphur, it boils also, forming an inodorous vapour of a deep yellow colour. This vapour sublimes into a powder of a red colour, or, when in more confined places, into dark globules of metallic lustre, and of the aspect of lead. Its specific gravity is a little more than double that of sulphur, being between 4.3 and 4.32, while sulphur varies from 1.99 to 2.072. It may be crystallized from fusion, and seems to affect forms similar to sulphur in the same circumstances. Like sulphur it is easily scratched by a knife, is brittle, and easily reduced to powder.

Selenium consists of two particles of sulphur, united by three of hydrogen, which gives rise to a very perfect form, (Fig. 52.). Its atomic weight is 26 [*]. It will unite in molecules of four, whose atomic weight is 104.

Selenious Acid.—When selenium is burned in a limited quantity of common air, it ascends in fumes uniting to oxygen. In this case, there are, however, two products, the nature of one of which is unknown, and the other is analogous to the fumes of sulphur. The product whose composition is unknown is a gaseous body, which possesses so strong an odour of horse-radish, that $\frac{1}{50}$th of a grain of selenium is said to be adequate to scent the air of a large chamber.

When selenium is burned in vital air, an acid results similar to the sulphureous, and consisting of one particle of oxygen on the pole of one of selenium. This is the selenic acid of older works. Its atomic weight is 36, composed of 26 selenium and 10 oxygen, or 100 of the former and 38.46 of the latter, which agrees with the determinations of Berzelius. These acid particles aggregate in quaternate molecules, whose atomic weight is 144, and, in the molecular state, it often enters into union. These molecules also give rise to crystals resembling those of nitre when they crystallize from solution. When crystallized from sublimation, they produce four-sided spicula.

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[*] Dr Thomson states it at 50, which is nearly the double of that in the text.

Selenic Acid.—Selenium also forms an acid perfectly analogous to oil of vitriol, in which a particle of selenium is inserted on each pole of a particle of water, three of oxygen being on the alternate segments of the water. Its atomic weight is consequently 94, or, excluding the water, which, however, is essential to its structure, it is 82. Its analogy to oil of vitriol, both in structure and properties, has been pointed out by Professor Mitscherlich. It is a colourless heavy liquid, having a powerful affinity for water, and giving out as much heat during the union as oil of vitriol. Its affinity for bases is also nearly equally strong; and the salts which it forms are in every feature analogous.

Seleniettted Hydrogen.—Like sulphur selenium unites with hydrogen, and forms an invisible fetid gas of acid properties. Hence it has sometimes been called Hydroselenic Acid. It acts with great energy upon the nose and throat, causing pain, destroying the sense of smell for some time, and producing catarrhal symptoms. Like sulphuretted hydrogen, it is absorbable by water, and its aqueous solution precipitates all the metals from their solutions of various colours. There are, no doubt, several compounds of selenium and hydrogen, but that examined by Berzelius possessed a structure similar to that of sulphuretted hydrogen. Berzelius analyzed it, by passing it through the acetate of silver. The oxygen of the oxide of silver, implied in the acetate, united with the hydrogen in the seleniettted hydrogen, and formed water, while seleniuret of silver was simultaneously generated. The composition of this seleniuret of silver was determined to be 1.389 silver and 0.499 selenium. But the silver, previous to the access of the seleniettted hydrogen, was combined with .101 of oxygen, which had engaged all the hydrogen united to the selenium in the seleniętted hydrogen, and formed water along with it. The quantity of hydrogen present, then, must have been one-fifth of .101 or .0202, and this was combined with .499 of selenium in the fetid gas destroyed. Now, .499 : 0202=104 : 4.209, that is, the analysis indicates a quaternate molecule of selenium united to two particles of hydrogen. One hundred inches of seleniętted hydrogen, disregarding its exclusive power on the radiant medium and accidental atoms, would weigh about 81 grains.

Sulphur and *Selenium.*—As might be expected, these nearly allied substances unite, and a substance results bearing an analogy to the sulphurets of arsenic. It is said to consist of 100 parts of selenium and 60.75 of sulphur, which indicates a quaternate molecule of the former and six particles of sulphur.

ARSENIC.

There is a very interesting substance which occurs in nature, both, in a free state, united to oxygen and to metals, bearing the well known name of Arsenic. It seems to occupy the same place in relation to the large metals, that sulphur does in relation to iron, copper, and other small metals. In the laboratory its habitudes are most analogous to the two substances which have been last examined, sulphur and selenium. When suddenly heated, it burns with a bluish flame, giving off a dense white vapour. It is very volatile, but not well suited to the liquid state; hence, like sulphur, it is readily obtained in a state of purity by sublimation. When in a solid state, it is a heavy body, with a lustre resembling that of steel: its specific gravity is commonly stated at a little less than double that of selenium, and about four times that of sulphur. From its lustre and weight, it has often been separated in chemical systems from those substances to which it is obviously related, and placed among metallic bodies otherwise most dissimilar. It is nearly as brittle as sulphur, and when it ascends in vapour, it gives out a smell not like horse-radish, but like garlic, which would be characteristic of arsenic, were it not that the vapour of phosphorus in certain states of engagement possesses a similar odour. What the odour of subliming sulphur may be, we have no opportunity of discovering, as it instantly unites with oxygen, and generates those pungent suffocating fumes which constitute sulphureous acid.

Arsenic is met with in the pure state, chiefly in primitive rocks, accompanying the ores of silver, cobalt, and copper. On considering the character of arsenic, and the circumstances in which it occurs in the mineral kingdom, it is very natural to conclude, that its form is like that of selenium, very intimately related to that of sulphur; and considering its very frequent occurrence, we at once conclude that it is analogous to two particles of sulphur, to which one particle of hydrogen is common, (Fig. 51). Its composition is therefore much simpler than that of selenium, which at once explains its more frequent occurrence. Its atomic weight is 18*. It must form itself into septenate molecules, three particles penetrating on each side of the equator into the concaves that are conformable to their poles. The atomic weight of such a molecule is 126. Like sulphur and phosphorus, arsenic unites readily with metallic bodies, rendering them brittle, and generally increasing their whiteness. The compounds resulting from its union with oxygen, are like those proper to sulphur and selenium, acid bodies and their number is probably great. There are only two, however, which occur in nature, and are possessed of much interest.

Arsenic Acid.—Arsenic acid consists of a particle of oxygen on the pole of one of arsenic, and therefore corresponding in structure to the sulphureous and selenious acids. When the arsenic is free from hydrogen or accidental atoms, the atomic weight of this acid is 28, composed of 18 arsenic, and 10 of oxygen; Thenard having found 18 arsenic and 10·1 oxygen. Most other chemists, however, have found the arsenic rather too heavy, which is only to be expected, when we consider the liability of the arsenic to become charged with hydrogen or accidental atoms of matter, and, where water is present, to degenerate into the state of arsenious acid, which is a more quiescent compound when in an insulated state. The arsenic acid is procured by supplying oxygen to the arsenious acid. As water is always present, the particles group in a manner perfectly similar to that which obtains in glacial phosphoric, and boracic acids, afterwards to be described; that is, one is inserted in each pole, and three are attached around the equator of a particle of water. The atomic weight of this molecule, then, is 152; and in the experiments of the laboratory, as in the case of glacial phosphoric, and boracic acids, it usually enters into union in these quinate molecules. The essential water is only 8·57 per cent. This acid has a sour and metallic taste; it attracts humidity from the air; it effervesces strongly with alkaline carbonates; it may be evaporated into a gelatinous mass, and reduced by fusion to a glacial state, but it cannot readily be made to crystallize. It is a very active poison.

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* Its atomic weight, given by Berzelius, is 94·077, which is nearly five times that of the text; and by Dr Thomson, 47·5, which is nearly two and a half times. The reason of this, rather unusual state in the multiples, will be seen when treating of arsenic acid.

Arsenious Acid.—Arsenious acid, at least in the dry state, consists of a septenate molecule of arsenic, with four particles of oxygen on the four poles, on one side of the equator. Its atomic weight is 166, composed of 126 arsenic, and 40 oxygen, or 100 arsenic, and 31·74 oxygen; Berzelius having found 100 and 31·907, and Thomson 31·57. Arsenic escapes during combustion in this state. Hence the alliaceous fumes of arsenic; for if all the poles were covered by oxygen, no such odour would be perceived. Arsenious acid also occurs in nature, constituting reniform, botryoidal, mammillated and stalactitic masses in veins and cavities where other arsenicated mineral bodies are found. It is sparingly soluble in water, which it renders highly poisonous. The arsenic acid of Dr Thomson, generated by infusing nitric acid upon metallic arsenic, consisted of this same septenate molecule, with all the poles covered by oxygen; its atomic weight is 206. There may be another acid, however, in which the ratio of arsenic and oxygen is 90, and 30 or 100, and 33·33, and whose atomic weight is 120. There may also be another analogous to the hyposulphureous acid of Gay-Lussac, in which the ratio is 100 arsenic to 28 oxygen. Upon the whole, it is not to be wondered at that different chemists, according to their different methods of manipulating, should develope different substances made of arsenic and oxygen.

Arsenic and *Hydrogen*.—Arsenic, like sulphur and selenium, with hydrogen gives rise to a fetid gas of very poisonous qualities. Two arsenicated hydrogens are easily conceivable, one in which there is one particle of hydrogen on a pole of a particle of arsenic, and which is therefore analogous in its structure to the hydrophosphoric gas of Davy, afterwards to be described; another in which three particles of hydrogen penetrate to the three concave regions of the arsenic, or are attached to the three angles of its equator, analogous to the light phosphuretted hydrogen of the same philosopher. In both cases, the density of the gases will be half that of hydrogen, in consequence of the great length of the axis. The specific gravity of the former gas, disregarding its liability to the insidence of atoms, and its exclusive powers upon the radiant medium, ought to be just about half that of common air, for its density is half, and its atomic weight very nearly the same, and therefore 100 inches ought to weigh about 15 grains. But the specific gravity of the other ought to be about .588, and 100 inches ought to weigh about 20 grains. If, in this gas, the arsenic were thrown down, 100 volumes would expand into 150 of hydrogen. Now, Gay-Lussac found, that in the gas on which he operated, 100 measures expanded to 140 of free hydrogen. The specific gravity of arsenicated hydrogen gas, also, observed by Tromsdorff, is stated at .5293;

while Davy prepared it lighter, and also with a specific gravity so high as .5552, numbers as near to those which have been anticipated from the atomic weight of the gas as could be expected. There can be little doubt, then, that such is the nature of this formidable sort of air, which closes a class of the most abominable substances in chemistry—the compounds of sulphur, selenium, and arsenic, with hydrogen.

Arsenic and *Sulphur.*—These analogous bodies may be readily united by art in several proportions. Two occur also in nature, constituting orpiment and realgar, highly coloured mineral bodies, which have been long used as pigments. Orpiment is of a lemon-yellow colour; realgar, aurora-red. Both are frequently met with crystallized. As is the case with most other sulphurets, the molecule is large. The analysis of realgar or hemiprismatic sulphur by Klaproth and Laugier, indicates that a quaternate molecule of sulphur is the nucleus, and that there is a particle of arsenic on each of its five poles; for this will require 40 parts of sulphur and 90 of arsenic; while the analysis of these chemists give 40 and 89. The nucleus of orpiment, or prismatoidal sulphur, again, seems to be a septenate molecule of arsenic, with a particle of sulphur on each pole. This requires 80 parts of sulphur, and 126 of arsenic; while the analysis of these chemists give about 80 and 130. Thus, in the red mineral, the sulphur is the nucleus, and all the poles are covered by arsenic; in the yellow mineral, again, the arsenic is the nucleus, and all the poles are covered by sulphur.

TELLURIUM.

When three particles of hydrogen are added, so as to supplement the equatorial region of arsenic, the form seems to constitute a particle of tellurium (Fig. 50). This is a substance of metallic lustre and considerable specific gravity, but met with so rarely, that chemists are very imperfectly acquainted with it. It occurs along with lead, gold, and the heavy metals; chiefly in Transylvania. In its general character it agrees with arsenic, but it is less volatile, and its fumes are not known to possess any odour.

Oxide of Tellurium.—Like the other ternate forms which have occupied our attention, tellurium unites with oxygen and hydrogen, the result of the latter union being an invisible fetid gas. The oxide examined by Berzelius appears to have had a structure analogous to white arsenic, being a septenate molecule of tellurium, charged by four particles of oxygen. The atomic weight of tellurium is 24; that of a septenate molecule 168, which, united to 40 of oxygen, gives the atomic weight of the oxide 208, composed of 168, and 40 or 100 tellurium, and 23.8 oxygen; Berzelius having assigned 100 tellurium and 24.8 oxygen. The atomic weight of tellurium given by Sir H. Davy, reduced to the oxygen scale, is 24.65 × 2, very nearly that of the text. The telluriate of lead, analyzed by Berzelius, gives protoxide of lead 260, or two particles and 207.64, or one particle of oxide of tellurium almost exactly. This oxide is generated in white fumes, when tellurium is set on fire by the blowpipe or otherwise; but it is believed that the odour of horse-radish, which Klaproth thought to be proper to the fumes of tellurium, belonged to those of the selenium which happened to be present in his specimens. The oxide of tellurium, according to the body with which it is associated, either plays the part of an acid or an alkali, which is a very interesting circumstance; and it is only to be regretted, that our acquaintance with it is so imperfect. But tellurium can too easily subdivide, in the process of polarized action, into arsenic and sulphur, to encourage us to hope that it will ever be found in great quantities. It does not belong to our age of the world.

Telluriètted Hydrogen.—Telluriètted hydrogen has not been minutely examined. It is a colourless body when in the gaseous state, but imparts a claret tint to water which holds it dissolved. It has not been ascertained whether, like the analogous compounds, it have acid properties. Its odour is not unlike that of sulphuretted hydrogen. As in the case of arsenic, a solid compound has also been noticed. Doubtless the possible combinations are very numerous. Tellurium has also been united with chlorine, under which the compound will be noticed.

PHOSPHORUS.

Of all inorganic bodies, there is none which possesses more interesting properties than that curious "consistent noctiluca" which was detected in the residuum of urine by Brandt. It shines in the dark like a luminous animal at ordinary temperatures, and shews farther its relation to light by being very strongly refractive, and becoming black or transparent according to the manner in which it is cooled. It has obtained the old name of Phosphorus, and consists of three particles of hydrogen, arranged as in sulphur, retained in position by two atoms of radiant matter, with the faces free as in the medium of light, (Fig. 53). Its atomic weight is 8. One hundred inches in the state of vapour, and in the same circumstances as to density and radiant matter as common air, would weigh 12·25 grains. Its form is nearly isamorphous with sulphur, though the substitution of two atoms of radiant matter, united only by three angles to each pole of the particles of hydrogen, instead of two particles of hydrogen forming a solid axis, introduces important modifications into its history and properties. It agrees more completely with sulphur, however, than any other body. It is a semitransparent sectile solid, which, being only procured from a state of fusion, corresponds to sulphur, when its crystalline structure has been changed by heat. It fuses at 108° Fahr., and is converted into vapour at a degree between the melting point of tin and lead. Like sulphur, it is nearly insoluble in water, but, like it, is taken up more plentifully by fixed and volatile oils. Whether in the concrete state or dissolved in its menstrua, phosphorus is luminous in the dark. It is extremely combustible, the heat of the hand, or the slightest friction, being adequate to set it on fire. The quantity of heat given out during its combustion is very great, and the scald which it occasions has some resemblance to that produced by contact with a minute particle of fluoric acid. This interesting substance, though it occurs in many situations in the inorganic kingdom, is not produced in great quantities. There are a few minerals in which it exists, and is found among the debris of their analyses, in union with oxygen and a base. But its characteristic region of development is the animal structure. There it seems to exist in greater or less quantity, in every fluid and solid, and it constitutes a large part of the bones of vertebrated animals. In the voltaic focus, and all vigorous experiments to decompose it, like sulphur, phosphorus gives off hydrogen; but its symmetry is so perfect, and the repulsion on the axis so small, that probably it may be long before it be decomposed in a notable manner. Its synthesis, however, is constantly exhibited within us and around us. Oxen on a meadow cannot get phosphorus to eat, yet it is formed in their bones sometimes in ounces every day.

As was implied when its inflammability was stated, phosphorus unites readily with oxygen, and the substances which result are very analogous to those of sulphur, with this difference, that the ratio most nearly approaching to saturation, is not 2 of the combustible to 3 of oxygen, as in the case of sulphur (oil of vitriol), but 2 to 2 or equality. Its greater lightness and etherial nature also impart to it greater mobility, and the compounds which it forms with hydrogen, though analogous to the sulphuretted hydrogens, are more numerous, possess still less stability, and are not known to be characterised by acid properties.

Fumes of Phosphorus. Phosphoric Acid.—When phosphorus burns in common air it is uniting to oxygen. When burned in vital air the combustion is most brilliant, and white fumes surmount the flame, which are for a time luminous. These fumes (Fig. 54) possess a structure analogous to the fumes of burning sulphur or selenium, and correspond to the sulphureous, selenious, and arsenic acids. They do not remain in a gaseous state, but aggregate into white flakes like those of snow, and condense on surrounding bodies. The ratio of phosphorus and oxygen is 8 : 10, and to that of the vital air consumed is that of 8 to some number a little less than 11. This explains the anomalous results obtained by noting the weight of vital air absorbed in the one case, and the quantity of oxygen evolved, when it is determined otherwise than by combustion. Thus, Sir H. Davy found, that 100 grains of phosphorus, to become phosphoric acid, consumed 135 grains of vital air. While M. Dulong having disengaged the oxygen from phosphoric acid by chlorine, estimated that 100 grains of phosphorus were united with 124.8 of oxygen. Now, 8 : 10 = 100 : 125, which are the true proportions, almost exactly those of Dulong. By noting the weight of vital air absorbed, the same quantity must weigh nearly $\frac{1}{11}$th more, or from 135 to 137·5 parts, as found by Sir H. Davy and others.

While phosphoric acid is kept dry, it constitutes a white flocculent substance, but on the least access of moisture, the particles group themselves around a particle of water, in the same way as the sulphur and oxygen in oil of vitrol, or the five particles of arsenic acid in a hydro-molecule of the same. Three particles of acid attach themselves to the equator, and two others insert their poles into those of the particle of water, as in Fig. 55. The atomic weight of a single particle of phosphoric acid is 18, that of a quinate hydro-molecule (5 × 18) + 12 = 102. A fully hydrated molecule must require 5 particles of water for each pole of the molecule, 6 for the equatorial parts, and 3 for the three naked poles of the phosphorus in the equatorial particles of acid, amounting in all, the nucleus included, to 20 particles of water for

5 of acid. A single particle fully hydrated when the bare pole is engaged in union with a base, possesses five particles corresponding to the five edges of its oxygen.

Hydrophosphoric acid absorbs water till it becomes an oily liquid, like oil of vitrol. Its difference of form and structure impart to it different properties in other respects. Thus, though it is intensely sour like the other, it does not corrode the skin. It is also much more reluctant to rise in vapour, requiring a red heat. By such a treatment, all the water may be driven off, except that engaged in the structure of the molecule, which is retained with such force that chemists are not agreed respecting its quantity. The true ratio is 11.8 per cent. Rose states it at 9.44, and Dulong at 17.08. When all the water not essential has been driven off, the acid constitutes a vitreous body, which has been called Glacial Phosphoric Acid. In consequence of the comparatively weak affinity of phosphorus for other bodies, this acid is decomposed with difficulty.

Phosphoric acid constitutes about half the earth of bones, and enters into the constitution of some rare and curious minerals, united to lime, alumina, copper, iron, lead, and some other bases. The balance of affinities in phosphoric acid is more perfect than in oil of vitriol. Hence there is a greater difficulty of developing other compounds of phosphorus and oxygen, as they constantly tend to produce phosphoric acid. Three others have been identified.

Phosphorous Acid (Davy)?—It may be generated, and the ratio of its elements at the same time indicated, by subliming phosphorus through corrosive sublimate, with a view to generate a compound of chlorine with a particle of phosphorus on each pole. When this body is mingled with water, both are decomposed; the chlorine gives rise to muriatic acid, and there remain oxygen and phosphorus from the decomposition of every particle of the chloride, in the ratio of 1 particle of oxygen to 2 of phosphorus. It is a somewhat volatile substance, inflaming in the air, and giving rise to phosphoric acid. The form is probably that of a quaternate molecule of phosphorus, with two particles of oxygen, one on each pole of the central axis, and consequently similar to the hyposulphureous acid of Gay-Lussac. Its atomic weight is probably 52; or, if it consist of two particles of phosphorus, one on each pole of the oxygen, it is 26. It may also be generated by subliming phosphorus in rare air. The quantity of oxygen per cent. is 62.5; calculated in vital air it is 67.5, as exactly found by Davy. But this acid does not possess stability.

Hypophosphorous Acid (Dulong)?—This acid possesses the form of the corresponding hyposulphureous acid, and differs from the preceding in having parted with one of the particles of oxygen from its pole. It agrees with the hyposulphureous in forming very soluble salts. Like it, also, it is a deoxydizing agent. Its atomic weight is 42, and its quantity of oxygen half that in the phosphorous acid of Davy.

Phosphorous Acid (Dulong)? *Hydrophosphorous Acid* (Davy)?—The foregoing unstable bodies, when united to water, probably assume several shapes, until they effect their resolution into a hydro-5-molecule of phosphoric acid, which is both a quiescent form, and possesses individuality without excessive magnitude. Of the probable forms, there are two which are eminent for their symmetry. One of these possesses the general contour of oil of vitrol, with this difference, that the three particles of oxygen on the equator have three of phosphorus on their poles, constituting three of phosphoric acid, while the central phosphorescent poles are yet naked. The atomic weight of this acid is 82.

Phosphorus, . .	5	×	8	=	40
Oxygen, . .	3	×	10	=	30
Water, . .	1	×	12	=	12
					—
					82

The ratio of its phosphorus and oxygen is 40 and 30, or 100 and 75. Now the ratios, in the phosphorous acid of Dulong, were 100 and 74.88, which almost agrees with that of Berzelius. This is the acid which, united to bases, gives rise to the phosphites, in which there is usually a particle of base on each pole.

Phosphatic Acid.—The most symmetrical molecule is when two particles of quinate hydro-molecules of phosphoric acid have only one particle of oxygen common to both; and this form appears to be generated abundantly when phosphorus is exposed to damp air, and enters into union with oxygen and water too slowly to form phosphoric acid at once. In its construction it is analogous to the native boracic acid. In its general characters it resembles hydrated phosphoric acid, but it possesses the odour of phosphorus; and, by the application of heat, it gives out its excess. Its atomic weight is 194, and when bases are presented it breaks up into phosphoric and hydrophosphorous acids. The ratio of its phosphorus and oxygen is 100 and 112.5. In M. Thenard's synthesis of the acid, 100 parts of phosphorus became 110.39 by the absorption of oxygen. This molecule is very analogous to some organic molecules. It is permanent in the air and oxygen gas, at ordinary temperatures, for there is not a bare pole of phosphorus exposed to the incidence of oxygen. By the application of heat, and by the accession of one particle of oxygen to every molecule, it breaks up each molecule into two hydroquinate molecules of phosphoric acid, which is the limit of all the compounds of phosphorus and oxygen. This acid is commonly regarded as a compound of phosphoric acid and phosphorus, which certainly there is no occasion to dispute.

Besides these, two other acids of phosphorus, though of delicate structures, seem possible. One, in which all the poles of the quaternate molecule of phosphorus are covered by particles of oxygen, in a combination producing a form analogous to the dry hyposulphuric acid; the other, in which the three symmetrically related poles of a quaternate molecule are covered. Others may also be constructed, but the tendency to assume the very simple form of phosphoric acid is so great as probably to prevent their development. The compounds of oxygen and phosphorus, then, may be thus expressed:

	Phosphorus.		Oxygen.		Weight.		Phosphorus.		Oxygen.
Phosphoric acid,	1	+	1	=	18	=	100	+	125
Phosphatic acid,	10	+	9	=	170	=	100	+	112.5
Phosphorous acid (Dulong)	5	+	3	=	70	=	100	+	75
Phosphorous acid (Davy)	4	+	2	=	52	=	100	+	62.5
Hypophosphorous acid	4	+	1	=	42	=	100	+	31.25

Phosphorus and *Hydrogen*.—The restlessness of phosphorus is remarkably shewn in its compounds with oxygen; but it is still more conspicuous in those with hydrogen; and many doubtless will be its evolutions in the animal system, until it find repose in the bones.

Of all the properties of phosphoretted hydrogen, none is so interesting as its spontaneous inflammability in the air. A bubble of this gas, as soon as it escapes into the atmosphere, takes fire with a gentle explosion, and, after a momentary flame, the acid fumes ascend in beautiful ringlets. One of these inflammable varieties is analogous in its structure to sulphuretted hydrogen, and may, like it, be best procured by a phosphuret deposited in water, such as that of lime. The phosphuret and water are decomposed together. The hydrogen escaping from the water unites with phosphorus, and they ascend in the same state of combination as sulphur and selenium, that is, a quaternate molecule of phosphorus has a particle of hydrogen on each pole; and the figure of sulphuretted hydrogen (Fig. 49) will serve well enough to illustrate both.

The refractive power of the compounds of phosphorus and hydrogen is extremely great, being surpassed only by hydrogen itself. Their exclusive action upon the radiant medium may therefore be inferred to be very great. But phosphorus, like sulphur, is always, when mingled with radiant matter, subject to the incidence of three atoms in every single particle, and nine in every quaternate molecule. This state of things would lead us to expect that experiment would be the best guide to the weight of these gases; but they are so perpetually changing, and subject to be mingled with free hydrogen, that apparently the most discordant results have been obtained. Disregarding the radiant medium altogether, that is, assuming that the exclusive power of the phosphoretted gas is adequate to balance the accidental atoms with which it may become charged, 100 inches of this gas ought to weigh about 27 grains*.

Dr Thomson has investigated and described the properties of this gas in a very satisfactory manner. The weight of 100 inches was found 27.5 grains. As every particle consists of six parts, four of phosphorus and two of hydrogen, it is easy to see what quantity of oxygen will be required to resolve it. Its particles are only half as densely disposed as the molecules of vital air. Hence, six particles of oxygen, or three molecules, will be supplied, by adding one volume and a half of vital air to one volume of the inflammable gas. In this case it will be wholly resolved into water and phosphoric acid. It may also be happily resolved into water and phosphorous acid, by supplying four particles of vital air to

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* Perhaps its real weight may be made up in this way :—

	Grains.
Weight of the same number of particles as in 100 inches of common air, deduced from the relative atomic weight and specific gravity of common air, . .	40
Twice as much hydrogen as is in 100 cubic inches, . .	4.2
As many atoms as in sulphuretted hydrogen, or 9 atoms, .	13.5
	66.7
A molecule of radiant matter excluded by every particle of the fetid gas, 1.5 × 8, ...	12
	54.7

Such, according to this view, would be about the weight of the same number of particles as in 100 inches of common air, but the phosphoretted hydrogen has, in 100 cubic inches, only half the number of particles; therefore 100 inches will weigh $\frac{54.7}{2} = 27.4$ grains. But, even supposing this view correct, the weight of the radiant matter is so rudely guessed at, that only an approximation could be expected.

every particle of the inflammable gas, that is, two to form water with the two particles of hydrogen, and two to the quaternate molecule of phosphorus, to form two of phosphorous acid. But four particles, or two molecules, of vital air occupy the same volume as one of phosphoretted gas; hence, for this purpose, equal volumes of the two gases will be required. These results have been found by Thomson.

A similar resolution may be effected by supplying oxygen in union with nitrogen, which serves also to illustrate the structure of the nitrous gases. Thus, if nitrous gas be infused, it is evident that twice as great a volume will be required to do the same thing as of vital air; for half the oxygen in vital air is here replaced by a particle of nitrogen, and the residuum will be a volume of nitrogen equal to half the bulk of the nitrous gas employed. If intoxicating gas be used for the decomposition, the same volume is necessary as in the case of nitrous gas; but the quantity of residuary nitrogen is double that when the latter is used, or equal to that of the intoxicating gas admitted; for every particle is adequate to constitute a molecule of nitrogen, in the same place which itself occupied before destruction. These experimental results have also been obtained by Thomson. Phosphoretted hydrogen may also be decomposed by chlorine, and its nature shewn.

This gas, however, is not quiescent, and when suffered to stand over water or mercury for some days, it undergoes a change of structure. The simplest resolution is that in which every particle breaks up into two, one of which has the phosphorus and hydrogen in the same ratio as formerly, one particle of hydrogen having a particle of phosphorus on each pole, and the other a particle of phosphorus with one of hydrogen attached. This change must be accompanied by the disposition of a fourth part of the phosphorus, as found by Dr Thomson. The biphosphoretted gas, the former of the two just mentioned, may again resolve itself into the true spontaneous inflammable gas, or that consisting of a quaternate molecule of phosphorus, with one of hydrogen on each pole. The other, or that which consists of a particle of each of its constituents, remains; and if it were removed, the phosphoretted hydrogen might again grow and decay, as formerly, and thus a sort of evolution go on in a very beautiful manner. This introduces us to another phosphoretted hydrogen gas, consisting of a particle of each substance.

Hydrophosphoric Gas (Davy).—This gas may be directly procured by heating solid hydrophosphorous acid out of contact of air. A particle of phosphorus is converted into phosphoric acid by the decomposition of one particle of water. This relieves one particle of hydrogen, which unites with the other of phosphorus not yet served with oxygen. Every molecule of the hydrophosphorous acid, then, can break up into four of phosphoric acid, and one of hydrophosphoric gas escapes. The gas which thus results, considered in binate molecules, possesses the usual density; or, considered in relation to the number of its particles, is as dense as vital air.

Disregarding the radiant matter, 100 cubic inches ought to weigh $(12.25 \times 2) + (2.1 \times 2) = 28.7$ grains, or to possess a specific gravity about twelve times that of hydrogen gas, as found by Davy, its discoverer. As in the former case, therefore, its exclusive action upon radiant matter seems to be nearly adequate to balance that with which it is liable to become charged. Every binate molecule contains two particles of hydrogen; hence the phosphorus between them may be replaced by a quaternate molecule of sulphur, and the same number of particles of sulphuretted hydrogen generated, which, occupying a double volume, expands one of hydrophosphoric gas into two of sulphuretted hydrogen. The same phenomena must happen when the phosphorus is thrown down, and the hydrogen permitted to resume its natural density. It evidently requires one and a half or two volumes of vital air to convert it into water and phosphorus, or water and phosphoric acid, as found by Dr Thomson. This gas is not spontaneously inflammable like the other. Both poles of the phosphorus are protected from the easy access of oxygen. These two gases, when mixed together in equal proportions, as in the state into which the inflammable gas standing over water has degenerated, when a fourth part of the phosphorus has been deposited, will require other proportions of oxygen to convert them into phosphoric acid and water. Every particle of the one will require two, and every particle of the other three of oxygen. The gas, when degenerating into this state, was not found to experience any change of volume; hence five particles, or two molecules and a half of vital air, are equal to consume one volume and a quarter of the inflammable gas, and this has been found by Dr Thomson.

We might conceive the ultimate state of the mixed gases to be a very beautiful molecule, composed of a particle of phosphoretted hydrogen, with one of hydrophosphoric gas on each of the poles, bearing a certain general resemblance to hyposulphuric acid, and occupying double the volume of the central body, and four times that of hydrogen, nitrogen, &c. There is nothing unreasonable in supposing a gas of this density, and it will be afterwards shewn, that as, in the present case, it is necessary to assume this, if we impart the most symmetrical position to the particles, so in the case of the fluo-silicic acid. In both cases, however, the supposition may be avoided with equal ease.

Perphosphoretted Hydrogen (Dumas)?—We found that, in sulphuretted hydrogen, one of the particles of the hydrogen was in some cases disengaged, and the supersulphuretted hydrogen resulting was a quaternate molecule of sulphur united to one of hydrogen, and, in this case, an oily volatile liquid was generated. When we consider the more buoyant nature of phosphorus, we might naturally conclude that such a body, the sulphur being replaced by phosphorus, would be gaseous, though, from want of buoyancy, it would only be of the usual density. The weight of 100 cubic inches of this gas, disregarding the radiant matter, would be 51.1 grains; and, supposing it fully charged with radiant matter, and the exclusive power of the particles the same as in the other, it would be $(51.1 + 13.5 - 12) = 52.6$. Now, M. Dumas weighed a phosphoretted hydrogen, which seemed to be of a homogeneous nature, and its specific gravity was 1.761, which corresponds to 53.7.

Phosphoretted Hydrogen (Davy's Elem.)—Besides these phosphoretted hydrogens, it might be expected that others should be developed in which the hydrogens penetrated to the centre of the phosphorus, and replace the atoms which may have been derived from the radiant medium. The simplest form which could result, in this way, would be one particle of phosphorus with three of hydrogen (Fig. 56), analogous to the arsenicated hydrogen. The poles of the phosphorus being completely exposed, spontaneous inflammability might be expected, but it would be distinguished from others by its great levity. It contains so much hydrogen, that we may suppose it as buoyant as the other spontaneously inflammable sort, and then 100 inches would only weigh $\frac{12{\cdot}25 + 6{\cdot}3}{2} = 9{\cdot}3$ grains. Now, Sir H. Davy obtained from the action of alkaline lixivia upon phosphorus, a spontaneously inflammable gas, only four times the specific gravity of hydrogen, which is about 9 grains; and it possessed the character proper to the constitution of such a gas as here assumed. Were the phosphorus of this gas thrown down, the hydrogen would evidently occupy $1\frac{1}{2}$ times the volume of the gas destroyed, or an expansion of one-half would follow; and Davy found that, in these circumstances, as by the action of hot potassium, two volumes became rather more than three, which consisted of pure hydrogen. But where this gas is developed, others may also be expected, and this will increase the weight, and modify the result. In the same way, a quaternate molecule of phosphorus may receive three particles of hydrogen in the concave equatorial regions of the lateral particles, or on their three analogous poles. Such a gas would weigh about 28 grains; and, when decomposed, would yield a volume and a half of hydrogen. Again, three particles of phosphorus may be accommodated on the three equatorial edges of a particle of hydrogen, from which will result a gas weighing about 39 grains. Upon the whole, the variety of phosphoretted hydrogens is extreme; and no doubt any one who will take the pains, will be able to shew that the apparent discrepancies in the analyses of different chemists of the first eminence, arise, as is usual, from their examining different substances, which their different styles of manipulating evolved.

The spontaneous inflammability of those varieties which have the poles of the phosphorus naked, render them curious; but the phosphoretted hydrogens are not known to perform any interesting part in the economy of nature. Their production seems to be confined to the laboratory. The simplest forms are,

	Phosphorus.		Hydrogen.	Atomic weight.	Weight of 100 inches.
A quaternate molecule phosphorus,	1	+	1	34	53 grs.
....	1	+	2	36	28
....	1	+	3	38	27
A particle of phosphorus .	1	+	1	10	27
....	1	+	3	14	9.7

Phosphorus and *Sulphur* unite in all proportions; and, as in the case of the union of sodium and potassium, which bear to each other somewhat analogous relations, and alloys of allied substances generally, the resulting substance is more fluid than either by itself. A large and very symmetrical molecule results, when a quaternate molecule of sulphur has on its single pole a quaternate molecule of phosphorus, and on its tripartite pole three particles of phosphorus. In this molecule the ratio of sulphur and phosphorus is that of 40 to 56, or 5 to 7, as found by Mr Faraday. The mass thus constituted remains liquid at the freezing point of water.

BORON.

The central region of Asia yields many chemical substances of a very peculiar character, and different from those which are found, in similar positions, in other quarters of the world. It holds, as it were, the same place, in relation to its inorganic forms, that Australia does in relation to its organic; and doubtless if chemists had the same curiosity as naturalists to wander over the face of the earth with a view to discover curious things, and contemplate the aspect of nature in every clime, a rich harvest of discovery would attend a journey to the lakes, springs, caves, and mountains of central Asia.

Among the saline bodies which have long been brought from the east, is crude borax or tincal, with whose natural origin chemists have not yet made us acquainted, though it has been well known in Europe for many ages. It is said to be the secretion from the superficial waters of a lake whose inferior strata contain common salt, to be held in solution by certain springs, and to effloresce on certain soils. It is said also to occur in the analogous region of South America, and to be met with in small quantities elsewhere. Borax is a pinguious saline body; and, by treating it with oil of vitriol, a substance is disengaged which forms thin white scales. The taste of this scaly mass is rather insipid, considering that it has been disengaged from an alkali which it neutralized as an acid. It is rather insoluble in water. Its solution changes vegetable blues to red, like an acid, but turmeric paper it reddens after the manner of alkalies. In its effect upon colours, then, it exhibits both an acid and an alkaline reaction, as the oxide of tellurium does in its habitudes with bases and acids. It is soluble in alcohol; and the spirit, holding it dissolved, burns with a beautiful green flame, which readily distinguishes this substance from others. Boric or boracic acid, for so this substance is named, occurs also in a free state, chiefly in volcanic springs, and much in the same situation as oil of vitriol. It also enters into certain minerals, in union with lime and magnesia. Its base is so tenacious of its oxygen, that it is only of late that it has been insulated, and its development was considered so great an achievement, that chemists, who were generally above such feelings, shewed themselves, on both sides, not a little on edge about the priority of the discovery. MM. Gay-Lussac and Thenard, named it *bore*; Sir H. Davy named it *boron*; and it was proved to be an olive-coloured, infusible, insoluble, insipid substance, fixed in the fire, and not very readily combustible. Its development in nature, in union with magnesia and lime, and associated with iron, induces the belief that some part of its form is that of magnesium, or calcium, or iron, which, as will be afterwards shewn, have certain isamorphous parts. Its tenacity of oxygen favours the opinion that the region to which the oxygens are attached, is parasitic, or consists of re-entrant edges, conformable to the equatorial edges of oxygen. It also shews its relationship to sulphur, by uniting to it, and occurring in similar situations, and along with gypsum. To phosphorus it shews its analogy, by a remarkable resemblance between the glacial or molecular phosphoric and boracic acids. Upon the whole, the boracic acid seems one that is generated out of the sulphuric, by the aid of magnesia, lime, or iron.

Now, if we suppose that a particle of sulphur has one of its poles covered by three atoms (Fig. 57), as will be afterwards shewn, that pole becomes isamorphous with one-half of a particle of magnesium, and it also becomes parasitic, and requires three particles of oxygen to supply it. Or, if the particle of sulphur be imperfect, wanting an atom on the pole, instead of which it receives three, it is then isamorphous with half a particle of calcium; and such a form might be generated by the incidence of a particle of iron instead of a particle of hydrogen into a particle of sulphur, deficient in one of the particles of hydrogen constituting its poles.

Boric or Boracic Acid.—Such a form as boron is evidently not fitted for insulation, however, for its poles are not symmetrical. Hence, on its reduction to the pure state, it will arrange itself in ternate molecules, (similar to those afterwards to be noticed under iron, &c.) By this the form is rendered symmetrical, three particles of boron being grouped round a triangular bipyramidal cavity, isamorphous with a particle of hydrogen. Hence, though it have a most intense affinity for oxygen in particles, still it will shew but little affinity till its molecular structure be destroyed by heat. These anticipations are fulfilled in reference to boron; for, while the affinity of the latter for oxygen, when they have been united, is so intense that they can scarcely be separated, boron may be heated in vital air to between the melting point of tin and lead, without burning. A little above 550° F. it enters into vivid combustion. But such a violent action as rapid combustion, even in cases where there are not the same difficulties in the way of a perfect regeneration of a natural body, as in the case of boron, is not well calculated to lead to a true knowledge of the composition of calces. Sir H. Davy burned a grain of boron, and it consumed 5.125 inches of vital air, which indicated that about 1.59 grains of oxygen had combined, and, therefore, 13 of boron, or one particle, had united with 20.67 of oxygen, which is almost exactly two particles. Now, it is to be remarked of the third particle of oxygen presumed to exist in boracic acid, that while the first two are placed conformably to each other, the third is not so. It would, therefore, require a higher exertion of affinity to deposit it; and it is very conceivable that, in the intense heat and repulsion of the combustion, the boron may have rested satisfied by two.

MM. Gay-Lussac and Thenard acidified a portion of boron by the aid of nitric acid, and it increased one-third in weight. Had 26 parts become 36 instead of 39, it would have indicated that a form had been produced analogous to soda or magnesia, when their metallic bases are reduced to natural oxides, in which two particles of base are on opposite sides of a particle of oxygen. But the experiment was only once attempted.

Sir H. Davy found that boracic acid contained so much oxygen that 30 grains of potassium were required to relieve 2.375 grains of boron. Now, as will be afterwards shewn, 30 grains of potassium, to assume their natural and quiescent state, demand six grains of oxygen ; therefore, 2.375 parts of boron are united in the boracic acid with 6 of oxygen, or 13 (the atomic weight) of boron is united with 32.8 of oxygen, which is as nearly three particles as could be expected.

Hydrogen appeared during the decomposition ; and, though this may have arisen from the destruction of a few particles of boron, the appearance of hydrogen in such circumstances always gives occasion to the suspicion that water was decomposed, and this would account for the small excess of oxygen.

But boracic acid occurs in nature in a free state. Are we to suppose that a body of this form, with three particles of oxygen towards one pole, and the other naked, will exist without finding some base with which it may enter into union? It is much more probable that two particles of boracic acid front each other, with a particle of oxygen between them, in a manner analogous to the phosphatic acid, which is also a very permanent acid, and that which naturally results from the slow combustion of phosphorus. An acid in this form can have much less tendency to combine. Its boron is 26, and its oxygen 70. Now, Berzelius states the proportions of base and oxygen in the natural acid at 26 and 74.65. The atomic weight of this acid, then, is 96; that of the boracic acid of the laboratory is 43. But how will the latter arrange itself in the laboratory? Two particles will certainly insert their naked poles in the concaves of a particle of water, like sulphur, phosphorus, selenium, arsenic, &c.; and then, doubtless, three others will attach themselves on the alternate segments of the equator, so that a quinate hydro-molecule will be generated analogous to that into which phosphoric and arsenic acids resolve themselves. The atomic weight of this acid is 227, aqueous nucleus included, or 215 without it *. Such

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* The atomic weight of boron, by Berzelius, is 13.931 ÷ 2 ; and that of boracic acid is 215.72 ÷ 8.

appears to be the structure of boracic acid. Like the analogous acids of phosphorus and arsenic, it melts on the application of heat into enamel, and otherwise resembles them. Previous to the application of heat, it has 15 particles of water in union with it; but, in the glacial acid, according to the view here advanced, there is only 5.8 per cent. of water. Boracic acid is of considerable value in the arts, in consequence of its power of taking substances, otherwise more infusible, into fusion along with it. Hence it is used as a flux in soldering, and in experiments with the blowpipe. Its most interesting compounds are those with soda, lime, magnesia, and the fluoric principle afterwards to be noticed. In this part of the system, indeed, the fluoric principle ought to be introduced, but it will be more convenient to treat of it in connexion with silicon, to which it is related in the same manner as boron is to magnesium, or rather to iron if we suppose its oxygerent pole hollow, and such, probably, will be found to be the character, at least, of the boron in the datolite found associated with iron.

THE VOLATILE ALKALI AMMONIA.

Ammonia has hitherto been justly considered one of the most interesting and perplexing substances in the whole system. By one method of decomposition it gives indications as if it had a metallic basis, and, in other circumstances, it is wholly resolved into two common and light gases, which appear to be among the most elementary of chemical substances. I believe these phenomena are well explained by the structure now to be assigned to it, while, at the same time, its relations to other substances are indicated in a satisfactory manner. It is true that it gives to ammonia an atomic weight considerably more than those assigned by most chemists; but the cause of this will be easily perceived; and analyses, though they be in general very various, are, upon the whole, more favourable to that here assigned, than that current, which is about a sixth part lighter.

Ammonia occurs in nature united with muriatic acid as a product of sublimation, in volcanic vents, and fissures beneath which carbonaceous strata are on fire. In union with fixed air, it is also obtained by the dry distillation of excrementitious animal substances. It is developed in the purest water of the laboratory, and during the decomposition of animal substances. Water, hydrogen, and nitrogen, are the three bodies with which it seems most immediately connected. But Mr Faraday, by the most unobjectionable experiments, has shewn that it may be obtained in any quantities from substances which contain no nitrogen, and apparently from a direct union of hydrogen and water *.

When speaking of nitrogen, it was remarked, that it could not be made to unite with hydrogen. This arises from the necessity under which the chemist lies of operating upon nitrogen in binate molecules (Fig. 14.), in which the combining region is locked up. Where nitrogen exists in particles, there can be no doubt but it exerts a very strong affinity for hydrogen,—an affinity very analogous to that which it exerts towards oxygen, wherein the symmetry of the combination is improved by a complete change of form. A determination towards the aqueous form, where that is practicable, is always to be discovered; and, in the present case, the conditions are favourable for its development. Suppose there are two single particles of nitrogen, each with one of hydrogen on its convex pole, if the nitrogens united into a binate molecule, the hydrogens would probably be discharged, (unless, indeed, there be in the animal system a hydracid composed of one molecule of nitrogen, and one of hydrogen, which would, probably, in the living body very soon become the muriatic, as will be afterwards shewn). But if the contact of these two particles of

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* Quarterly Journal of Science, No. xxxvii.

nitrogen were prevented by the interposition of a particle of hydrogen between them (Fig. 61.), then, by a simple condensation of the axis, the whole would be immediately changed into a double molecule of water, with a solid axis of hydrogen (Fig. 58.). This is a particle of ammonia. Its atomic weight is 26, and its molecule is ternate, senate, or septenate, as in the case of water. The atomic weight of the last is 182. This form may be also immediately generated by the incidence of a particle of hydrogen into the pole of a particle of water, and the evolution of a symmetrical form by the incidence of another particle of the latter on the other pole of the hydrogen. This is an union which would certainly often take place in the laboratory, were it not for the determination of free hydrogen to the gaseous state.

It is easy to see how this form may also be developed during the sublimation of carbonaceous substances, as will be afterwards more minutely shewn.

The phenomena of the decomposition of ammonia are very interesting. When treated in the voltaic focus, in such a way as might be expected to insulate its metallic basis, if it had any like the fixed alkalies, the mercury prepared to receive it becomes solid, increases in size about five times, with an addition of weight amounting only to about $\frac{1}{100}$th of the whole. It acquires, at the same time, the aspect of a true amalgam or alloy of mercury and another metal. But the compound, whenever an attempt is made to insulate the metal, which seems to be amalgamated, is immediately resolved into mercury, ammonia, and hydrogen. For this purpose, it is only necessary to shake the mass a few minutes in a glass-tube, after which a globule of common mercury occupies the bottom; and the air in the tube, without having suffered any change, contains a quantity of hydrogen, and ammonia mingled with it *.

Such are the phenomena presented by ammonia at the

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* Gay-Lussac et Thenard, Recherches Physico-Chimiques, t. i. p. 61.

negative pole of the voltaic axis in contact with mercury. When, again, a volume of ammoniacal vapour is visited with a succession of electric discharges, it is found to be wholly resolved into hydrogen and nitrogen. Now, these seemingly anomalous resolutions naturally arise out of the structure here assigned to it, and serve, at the same time, to point out the true nature of nitrogen, and the influence of an unipolar electric state, instead of natural electrical repose. When under the metalliferous induction of the mercury, and of what may be regarded as the metalliferous pole of the voltaic axis, those particles of hydrogen, which are not attached to the axis, are given off, and a form (Fig. 60.), which is that of arsenic, without its two terminal particles of hydrogen, remains; into the concave poles of this, the projecting ternate angles of the mercury are probably inserted, which gives occasion to those arborescent shootings that are observed to take place. When the electric restraint is removed, mercury and ammonia are regenerated; and were this to take place without the aid of any foreign substances, the volumes of ammonia and hydrogen resulting must be two of the former to one of the latter. For one particle of ammonia can yield as much hydrogen as is required by a contiguous one, to change it into ammonia, and a particle more than is required: every particle of ammonium (Fig. 60.) consists of 7 of hydrogen, and it wants 6 of hydrogen to become a particle of ammonia: hence, during the destruction of the septenate molecule of hydrogen or ammonium, a particle of the volatile alkali and one of hydrogen escape together. But a particle of the volatile alkali occupied double the volume of a particle of hydrogen. Hence we see the accuracy of Davy's statement, that, in the most accurate experiments, the proportions of ammonia and hydrogen developed in such experiments are two to one in volume. Could ammonium be obtained in a free state for the purposes of chemistry, it would probably be far more powerful in obtaining hydrogen for itself out of other bodies, than potassium is in obtaining oxygen. This form, however, has not yet been made to exist, except in combination with metals, which it renders lighter and more brittle.

Such are the phenomena presented by ammonia along with mercury.

When ammoniacal gas, again, is destroyed by the violence of the electric discharge, as in the other case alluded to, hydrogen is set free; and the particles will evidently depart in pairs, the shock which drives off one acting instantly with equal violence upon that which corresponds to it on the other side of the equator. There remains now two parts composed of hydrogen, in such relations, that, were it not for the axis, two particles of oxygen would immediately result. But the twisting round of the particles into the form of oxygen is completely prevented by their engagements parallel to the axis with the central particle of hydrogen. Hence, as in the case of cyanogen, afterwards to be described, a symmetrical form is evolved by their union at the poles; and the residual form, after two particles of hydrogen have been expelled, is composed of two particles of nitrogen, with one of hydrogen between them. The next shock relieves the hydrogen; and thus, from the destruction of every particle of ammonia, a molecule of atmospherical nitrogen and three particles of hydrogen result (Fig. 62.). This electrical analysis, then, is the reverse of that synthesis by which it was supposed that ammonia is often generated in decaying animal substances.

In relation to its volume in the gaseous state, ammonia fills as much space as a double molecule of water, with which it is isamorphous, or as two volumes of the aqueous vapour, hydrogen or nitrogen would do. And when each particle or double volume is broken up into four parts, the resulting volumes ought not to be four times that of the ammoniacal gas destroyed, but only double; and it is universally agreed, that, were the decomposition complete, this would be accurately found to hold.

The aqueous and the nitrogenous form appear to be curiously combined in ammonia, in certain cases of its union with metallic particles, which exert a powerful action in inducing a quinate distribution of parts. The result is Fig. 59. Thus, when an atmosphere of ammonia is placed over hot potassium, the metal enters into a quinate arrangement, analogous to that which it does with chlorine or oxygen, by resolving the six particles of hydrogen, or one of the poles of the ammonia, into a particle of nitrogen; and the change is consequently accompanied with the disengagement of as much hydrogen as if the same quantity of potassium decomposed water.

Such are the phenomena of the destruction of ammonia. It is not to be expected that an inorganic apparatus should be adequate to its development in large quantities; for nascent hydrogen and nitrogen are not often found in the laboratory. It is usually obtained by disengaging it from sal ammoniac, by the aid of quicklime.

Ammonia can only be expected to prove itself to belong to the ternate system, and to shew its intimate relationship to water. Disregarding its action on our nerves, which give us most complex and difficultly intelligible intimations respecting the state of the matter which touches them, ammoniacal gas or vapour comports itself very like steam. When kept dry, it is indeed a permanent gas of much greater density than steam at ordinary temperatures. But, like alcohol, and ethers, to which, as will afterwards be shewn, it possesses certain relations of form, it is a much more volatile body, and less fitted for the liquid state. On being admitted to water, upwards of 500 volumes of it are absorbed by one of water. It settles in it immediately as if it were steam, and the liquid acquires all the chemical properties of the gas. The ammonia may again be expelled by heat, or exposure; and the aqueous solution always emits pungent alkaline fumes.

Were the exclusive power of ammonia upon the radiant matter the same as that of water, 100 inches, in the state of gas, ought to weigh as much as $\frac{200}{3}$ inches of steam, together with 50 inches of hydrogen, or about 20 grains in all. Its refractive power, however, is greater, and accordingly it is found to weigh about 18 grains. Its atomic weight, compared with common air, brings out its weight at 19.5 grains; but its specific heat is greater, and nothing can be inferred from the specific gravity of such a gas, to within two or three grains, or 100 inches.

Ammonia possesses powerful alkaline properties; or, we may say that it agrees with water in uniting with acids, and in rendering vegetables green. Its affinity for the powerful acids, however, in consequence of its greater magnitude and force every way, is much greater and much more powerful. Hence it is displaced with more difficulty than water. Spirit of salt, or oil of vitrol, united to ammonia, may be handled without the fingers suffering, and this we ascribe to the circumstance, that the acid is neutralized by the alkali. But if our fingers, like those of a calcined statue, happened to be made of lime, we might almost as well handle spirit of salt as sal ammoniac; and it would be true, that, in as far as our sensations were concerned, the acid united to the sal ammonia was as little neutralized, as with our present fingers we find it to be when it is united to water. It can only be said that water is a weaker base than ammonia. Ammonia, however, is always alkaline; but the condition of water is so beautifully poised between acid and alkali, that the character either of the one or the other is induced according to the demands of the body with which the water is associated.

The volatile alkali is, like the strong acids preserved in the laboratory, dissolved in water, and the same reasons which led us to anticipate a certain number of particles of water as those necessary to hydrate each acid according to its form, lead now to anticipate six as the number necessary to hydrate one of ammonia; that is, one for each edge of the equator. The atomic weight of ammonia is 26, and that of six particles of water is 72; hence in this symmetrical liquid, composed of hydro-senate molecules of ammonia, the ratio of ammonia to water ought to be 26 to 72, or 26.5 to 73.4 in 100 parts.

Now, Dr Ure begins his table of aqua ammoniæ with 26.5 ammonia, and 73.5 water!

CARBON.

In our inquiries into the atomic constitution of natural bodies, we are naturally anxious to find a form to suit the properties of carbon, which, after water itself, performs the most curious and admirable part in developing the beautiful series of organic forms. We have seen that there is something very eminent in the structure of water and nitrogen, the other organic elements; doubtless we may expect the same in carbon. Now, the form into which atoms of matter resolve themselves most simply, after hydrogen itself, is that of a pentagonal bipyramid (Fig 4.), for which the mind immediately contracts the prejudice that it is carbon. Its atomic weight is 5. Its capacity for heat is less than that of hydrogen, and greater than that of oxygen. Though no fewer than five faces are opposed to each other, it could not be easily expanded into another form; for five atoms cannot constitute any other form, and the equatorial angles are separated from each other by 1° 28′. Or if it be thought the force of the attractive fluid is sufficient to bend the yielding matter at the angles to perfect cohesion, still there will be an opening to that amount between the edges, admitting of a free movement of the repulsive fluid, without explosion, expansion, or destruction of the form: we should say then, that this decaedron is a form very easily developed, and very difficultly destroyed. Now, carbon appears to be a very permanent body, occurring even in great masses among primitive strata, both as anthracite and plumbago. In the voltaic circle, charcoal does indeed give off hydrogen (and every particle of carbon may be regarded as composed of two of hydrogen and an atom of matter); but it might justly be concluded, that charcoal could never be prepared completely free from water or hydrogen;

and unless hydrogen were obtained from carbon, precipitated from carbonic acid, or, if otherwise, in large quantities, it would be rash to conclude that it had ever been destroyed in the voltaic focus to any considerable extent. Like its capacity for heat, its electrical state of carbon is intermediate between hydrogen and oxygen. In both respects, then, it fills up the chasm between them, and it is consequently capable of uniting with hydrogen on the one hand, and oxygen on the other.

Every particle has seven prominent solid angles, five on the equator, whose opposite edges, as in hydrogen, are in the same plane, and two on the poles. Were the directions of the polarizing axes determined by the polar angles only, they would be the same as in nitrogen, or inclined to the axes at an angle of 47° 37′ 56″. The resultant direction is the mean between this and the direction of the equatorial axes, which gives 67° 48′ 58″. Now, the observed singling angle of the diamond, which consists of pure carbon, is given at 68° 2′. The refractive and exclusive power of carbon, then, must be very great.

Carbon cannot be reduced to the fluid state by any heat which the chemist can command. It evidently cannot give rise to laminæ like water, for three particles, when their edges are placed parallel, form a solid angle. As obtained for the purposes of experiment, it usually possesses the woody structure. Charcoal is nothing but wood, with the water driven out of it by heat. By other means carbon may be procured as a black powder. In both cases it is known by the name of charcoal, and its chemical properties are in both cases the same. It is destitute of taste and smell, and is of a very insoluble and indestructible nature. Hence piles which are to be driven into water are previously charred on the outside, which renders them insoluble by the water, and much more durable than when the cellular or aqueous tissue of the mass is permitted to remain. It also possesses the property of restoring to a wholesome state, putrescent water or meat, perhaps by occupying both the free oxygen and hydrogen, and constituting pyroligneous acid, which may neutralize any alkaline matter that may have been developed, and, by resolving the free oxygen, hydrogen, and ammonia, which were effecting the decomposition, into a small quantity of an acetate, prevent the progress of the putrefaction. Or its electric state may be such as to induce a state upon the putrescent medium, the reverse of that which gives rise to putrefaction, and thus, without itself entering into union, it may act directly as an antiseptic. The particles of carbon may evidently group together in different ways, which demand our attention.

Of the symmetrical molecules into which it will resolve itself in different circumstances, the most easily produced is the ternate. It has this peculiarity, that the concave centre is exactly conformable to the pole of a particle of hydrogen, (Fig. 63). The atomic weight of this ternate molecule is 15, and those irregular masses of carbonaceous matter constituting plumbago, anthracite, and the various coaly bodies, are probably composed of a congeries of wavy laminæ of carbon, partly in single particles, partly in ternate molecules, irregularly disposed, hydrogen and water being also often present in large quantities. The hardness of carbon in different states is very different, and it varies in its action upon light from that which is unable to sustain a single ray, to that which possesses a lustre as high as cast-iron. Such is the lustre of coke, which is coal deprived of its volatile parts by close burning, and consists chiefly of carbon. This coke when withdrawn from the furnace, possesses a columnar structure like starch or basalt, and on ledges are often to be observed beautiful shrub-like forms, indicating that the carbon was subliming. Vitrified surfaces are also to be seen, but as a portion of silex and fixed alkali is present, and other impurities, these may have aided the fusion of the surface.

The next remarkable molecule is that in which five particles are united by one edge, (Fig. 64). This molecule has all the stability of carbon itself, and consequently cannot be resolved into it, nor recognised as the same substance. Its atomic weight is 25, but it is so deficient on its polar regions, and so highly conformable to quinate bodies, especially nitrogen (Fig. 12.), that it may be expected to occur in nature chiefly in union with nitrogen, and we shall afterwards find that this constitutes one of the most interesting substances of the chemical system.

The next is a septenate molecule, in which both the poles of the former are covered by two of carbon, (Fig. 65). This also is a body of very interesting characters. Like the former it possesses great stability, and cannot be resolved into carbon.

But all these molecules are merely rudimentary compared with the duodenate, in which twelve particles unite by all their equatorial edges; from this there results a pentagonal dodecaedron, every face of which is surmounted by a pentagonal pyramid. The lines joining the apices of contiguous pyramids lie in the plane of the faces interposed, so that the form may be described as a regular triacontaedron, the faces of which are lozenges, (Fig. 66). This beautiful form is a molecule of diamond. We see, then, how well the molecules of the diamond are calculated for giving rise to that octaedral cleavage, and those highly polygonal tessular forms in which it occurs in nature. The atomic weight of the diamond is 60. Its cohesion is so perfect, and its angles so sharp and strong, as to resist breaking or turning aside; so that we only expect to find that the diamond is the hardest of all bodies. The surface of a fractured diamond must also be the same in detail as that of a polished one, consisting merely of unbroken molecules, arranged symmetrically; and it is remarked, in reference to the diamond, that while other gems when excited electrically by the same substance, give different electricities according as their surfaces are fractured or polished, the diamond always gives the same. The subtile repulsive fluid must evidently be in a state of great quiescence. But it is great in quantity, and is very capable of excitement. Hence the diamond will not easily transmit electricity.

Though carbon is most abundant, the diamond is very rare, and it does not appear that it has yet been prepared by art. The presence of hydrogen must prevent its development, and to evolve it from fixed air or carbonic oxide would probably require the time and tranquillity in which the beautiful forms of nature are produced. But by strewing the vessel with diamond powder so as to dispose to its evolution, one would think that chemists might be able to produce a specimen of the diamond, especially when such compounds have been discovered as the bicarburet of hydrogen of Mr Faraday, in which every particle seems to contain all the carbon in a molecule of diamond, and only a small proportion of hydrogen.

Carbon is a combustible body, burning without flame; but in the state of diamond, its combustion is so extremely difficult, that it has only of late been proved. The combustible and unctuous nature of the diamond, however, seems to have been a very old idea. Boethius de Boot, in his curious History of Gems and Stones (the first edition of which was published at Frankfort in 1609), concludes, after some very sound reasoning, " Adamantis materiam igneam et sulphuream esse, aliarum gemmarum vero aqueam." This opinion of De Boot received confirmation from the optical researches of Newton, who showed that it agreed with combustible bodies, rather than other gems, in its high refractive power. When he says incidentally, however, when speaking of the diamond, " which probably is an unctuous substance coagulated," (Optics, p. 249), he is evidently ingenuously alluding to the opinion of De Boot.*

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* This author is illustrating the means by which lapidaries were in the habit of distinguishing true diamonds from gems and pastes, by the use of a compound of gum-mastic and ivory black, which adhered to the diamond in a manner very different from other gems. In this argument he says, "Gummi cerasorum aquæ misceri ac in ea dissolvi potest, quod aqueæ sit naturæ. Gummi-masticis nequaquam, quia igneæ est naturæ, oleo ob id facile jungitur, a quo etiam dissolvitur, ut omnia alia quæcunque igneæ sunt naturæ, et facile in flammam redigi possunt. Quod itaque mastix, quæ igneæ naturæ est, adamanti facile jungi possit. Signum est id propter materiæ similitudinem fieri, ac adamantis materiam igneam et sulphuream esse, atque ipsius humidum intrinsecum et primogenium, cujus beneficio *coagulatum est*. . . . . Qui hac a me ratione contentus non est, meliorem adferat; interim sciat rerum *vim* et similitudinem, ut plurimum ignotam esse.

We could easily believe that it would be difficult to destroy a molecule so symmetrical, and, when cold, so firmly bound together; but all the poles are placed so favourably for the incidence of oxygen, that we might also infer, that, at a high temperature, it should be carried off in particles of fixed air. It may indeed be worth inquiry, whether old diamonds, which have been exposed to the air, and not rubbed, be not covered with a coating of oxygen. It is remarked that diamonds are rendered more brilliant by being put in the fire; and, if this be the fact, it is difficult to see how such an effect could take place otherwise than by driving off a superficial film of oxygen or carbonic acid. If we suppose diamonds liable to such incrustations, it would enable us to explain the great differences in refractive powers which have been found in different specimens of this gem, the index of refraction being given by different observers, from 2.755 to 2.439.

As the molecule of the diamond is hollow, its weight is not very great. The specific gravity of different sorts varies from 3.55 to 3.44, which is about twice as much as that of anthracite, and four times as much as Mr Faraday's bicarburet of oxygen. Diamonds frequently occur of all the colours of the spectrum: they are sometimes even black. This is said to be the colour of diamond-powder; and it is not improbable, that, in pounding a diamond, some of the molecules may be broken by percussion against others, and thus the diamond dust be mixed with carbon, which would make it more or less a black colour; but a powder composed of molecules of diamond, would probably reflect light in a very beautiful manner. The

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quemadmodem ferri et magnetis." See Gemmarum et Lapidum Historia, quam olim edidit Anselmus Boethius de Boot, Brugensis, Rudolphi II., Imperatoris Medicus. Nunc vero recensuit, &c. Adrianus Toll. Lugd. Bat. M.D. 1636, p. 117. It has been the fate of this ingenious naturalist to be forgotten; but his reasoning is better than that relating to refraction, for it both argues the combustible and carbonaceous nature of the diamond, while the other would directly mislead us as to both particulars. There are several bodies of a crystalline and stony nature agreeing with diamond in refractive power, but none of them is combustible or carbonaceous except itself.

diamond has long been justly esteemed as the most beautiful of gems. Of late it has been brought into the service of science for forming caps for time-pieces, and lenses for microscopic observations; its high refractive and low dispersive power, together with a freedom from double refraction in homogeneous specimens, rendering it very highly valuable for the latter purpose.

Such are the molecules which naturally arise from the grouping of particles of carbon by their equatorial edges, a mode of aggregation to which the force of symmetry determines, when the other mode cannot give rise to symmetrical and individual forms. This other mode implies the union by a terminal edge, and the adhesion of polar to equatorial angles. Such an arrangement will constantly obtain, where particles of carbon unite one by one successively, and where a medium exists possessing a structure capable of sustaining, without destruction, the curious spiral which must result.

When two particles of carbon are united by a terminal edge, and with their axes parallel, they constitute a polarized axis disposed to attract other particles to both extremities, or, at all events, to that extremity which is in a state consecutive to that of the carbon contiguous. Let us suppose the axis of the united particles vertical, and the summit in a positive state. The particles of carbon being positive, will most readily be attracted to the inferior or negative pole of the polarized axis, constituted of two particles of carbon, united by a terminal edge. But a third particle cannot be placed in a parallel manner to the other two, so as to give rise to a straight line, as we found to obtain when aqueous particles united by their equatorial edges. Such a straight axis, consisting of particles placed zigzag with the poles of the alternate particles touching, is indeed possible; but the more simple mode of arrangement, and that in which the particles are placed at the extremities of the axis previously existing, is, when the third particle attaches itself to an edge belonging to one of the two particles of carbon formerly attached, both whose angles are free. Now, this edge is not parallel to that by which the first and second particles are united. Two edges are equally inclined to it by an angle of 30°. To which of these will the third particle attach itself? This is evidently a very interesting inquiry, and will depend upon the phenomena of electromagnetic rotation. Suffice it to say, that if there be a positive electric pole at the summit, as has been assumed, and a south magnetic pole, the third particle of carbon will be placed at the inferior extremity, so as to give origin to a sinistrorsal helix, or one revolving from right to left. In this way particles will be successively added, and a spiral filament of carbon (Fig. 67) will result, of which twelve particles are involved in every symmetrical revolution.

Of such spiral filaments, placed contiguous to each other, and arranged around the same axis, a tube may be constituted, whose walls shall be impervious. In this the spiral structure is obliterated, except in as far as the cohering edges, being inclined obliquely to the axis, may be regarded as spirals turning to the right or left around it. Such a tube would be a most minute fibre, capable of transmitting only hydrogen or radiant matter.

But the tendency of every polarized axis, is to place every newly attached particle in a parallel position to that which is in the consecutive state. Hence much larger spires will often be determined, than those which imply only twelve particles in one revolution, and spires proceeding together will give rise to tubes of various diameters, and with walls more or less dense, or pervious, but such that they will resemble, in structure, a ribbon wrapt round a ruler, which is withdrawn when the ribbon has been fixed in its spiral position. Besides these, there are other sorts of spiral filaments, which will naturally arise from the successive deposition of particles of carbon; for when they are united by their opposite faces, a spiral structure is instituted, and when, by their equatorial edges, most nearly opposite, a spiral can only be prevented by every particle refraining from uniting with any other, by a terminal edge, a state of things which is extremely improbable. Let us now inquire whether nature exhibits to us any such carbonaceous spires. It might be remarked, that the diamond affords evidence, that carbon may exist in some other adamantine arrangement than the duodenate molecule. A crystalline congeries of such molecules, must be homogeneous in every part, but it frequently happens that tortuous portions occur in diamonds, which cannot be polished in the same manner as the surrounding parts, and which give rise to an irregular and even double refraction. Now, nothing seems more probable than that during the development of a diamond, the spiral arrangement should sometimes interfere with the tessular deposition of the perfect molecules, and give rise to the phenomena observed.

But it is evidently not in the mineral kingdom that we are to look for the spiral structure. It is in the vegetable kingdom that particles of carbon, moving freely, are successively secreted into the same cell, and presented to each other in circumstances favourable for the institution of this arrangement.

Now, the spiral vessel in the vegetable structure has for a long time excited the interest of vegetable anatomists, and completely fulfils all that we should expect from the spiral grouping of carbonaceous particles. In the leaves and young stems of trees, shrubs, and flowers, between the fibrous and the cellular part of trees, that is, in the partially organized wood near the pith and bark, in the tubers attached to the roots; in a word, in every part of the vegetable structure, recently formed of sap elaborated by the leaves, spiral threads are found, having all the characters which we might suppose those of carbon to possess. They have an adamantine whiteness, and possess so great cohesion, that they may be very much extended before they are broken. They seem generally to proceed together in a group, advancing from the region of vegetable assimilation, that is, from the leaves, and they proceed downwards almost to the root. Sometimes the tubes resulting are associated in a fasciculus, at other times they are solitary, and, when torn asunder, indicate that they are composed of a great many spiral threads, somewhat loosely connected among themselves.

Perhaps, it is scarcely carrying our illustration too far, to inquire into the direction of the vegetable helix. It is well known that the superior aspect of natural objects, possesses a south magnetic polarity; and the recent researches of M. Pouillet prove, that the superior aspect of vegetables, during vegetation, is in an electro-positive state, as indeed seems always to be the case with that region where the greatest chemical action is going on, supposing that there is nothing in the structure to determine it otherwise. This condition, then, ought to determine the revolution of the spiral vessel from right to left. There may be many plants, however, in which these conditions are reversed, and more especially until observations as to the polarity of bodies in the southern hemisphere shall have been extended, we need not press the illustration. Hales, however, asserts that the spiral vessel in plants uniformly turns from right to left, and it cannot be doubted that this is the most general state of the structure in our common plants.

How many particles of carbon may be involved in the spire of a vessel large enough to be visible, it may be difficult to guess; but it will vary in different plants, according to the style of their organization, and their vegetative force. The simplest sort is that of which the spiral structure cannot be detected, in consequence of its minuteness and compactness, and in a single spire of which only twelve particles are involved. It can transmit only hydrogen or atoms. It would not be distinguished from the most minute fibre visible.

Vegetable anatomists have had many inquiries into the structure of the spiral vessel, and some have said that they have seen that the spire itself was a tube, and others that it was a concave or semicylindrical ribbon; whilst others have been unable to see either structure. I have endeavoured to inquire as to these matters with globules, lenses, and compound microscopes of very efficient qualities (though always of glass), but could not satisfy myself that such optical instruments, or even the eye itself, is adequate to exhibit the ultimate vegetable organization. As in other matters which reach to the atomic combinations of bodies, we must probably make synthesis precede analysis.

The structure which has now been assigned to the spiral part of the spiral vessel, induces the belief that it is a vessel of much weaker chemical agency than the aqueous tissue. The angles directed towards the centre are not so pungent, and their specific heat is much less. Neither is there any thing so remarkable in their electrical state. They are altogether much less fitted for elaborating sap than the cells and intercellular canals of the aqueous tissue. They are indeed unconformable to water; and it seems very probable that water, if contiguous to them, would become attached to their sides. In illustration of these views, it is remarked that spiral vessels, whether possessing a structure that may yet be torn out into a spiral filament, or fixed by the accretion of particles of water, &c. so that their resolution is no longer possible, never contain a liquid but only aëriform matter; hence they have been denominated Tracheæ. It is natural to suppose that, as the spiral vessel becomes older, it shall become more dense, by the accretion of carbonaceous and aqueous particles on its sides; and the ultimate state into which it can resolve itself, when the activity of the subtile fluid which developed it is over, seems to be a rectilineal fibre, composed of carbon, with that quantity of aqueous matter attached which neutralizes the electric state of the carbon, and gives rise to a quiescent neutral mass, which is the crisis of change, and the limit of the vegetable action. This tissue constitutes wood, which, when reduced to its elements, seems to consist of water, in the ratio of a senate molecule, and carbon in the ratio of one symmetrical spire. From this, however, it does not by any means follow that the structure of all woods is the same. Particles of different sorts, when united in the most perfect manner, as when their union is effected by organization, are generally associated in their quiescent ratio. But the multitude of forms in which this quiescent ratio may be sustained is immense. Hence the origin of that wonderful variety of vegetable products, which give nearly the same results in analysis. The ratio of the quantity of carbon which constitutes a spire to a molecule of the aqueous tissue, is (60 : 72) 45.45 carbon, and 54.55 water in 100 parts; and this seems to be very nearly the quiescent ratio of that which forms the woody mass; and where the ratios yielded by analysis are very different from this, we may suspect that oxygen and hydrogen, as well as water, are present.

It has been already shewn that, in monocotyledonous plants, or those in which the aqueous or cellular tissue predominates, three, the determinate number of water, is constantly reproduced. In the more carbonaceous vegetables, or those of a higher organization, the dicotyledones, the determinate number of carbon, or five and its multiples, is no less conspicuous. The parts of the perianth, and the number of essential organs, generally belong to the quinate system; and each verticillus of the fructification consists of a quinate number of parts. At other times, again, it requires more than one set of organs to evolve this number. Thus, in the Cruciferæ, the second and third verticillus taken together, afford ten parts, four petals and six stamens; and the external and central parts again afford five parts: this, however, is pressing the argument. But many of the parts are, as they occur in nature, abortive, and the quinate numbers are consequently imperfectly developed. Besides this, it is only to be expected, that, while the aqueous tissue should determine towards the number three, and the carbonaceous towards the number five, their resultant, or four, should be often developed, and this is indeed the case. There are many tribes of plants, in which the numbers four and eight, and a few in which even twelve prevails. The contest is beautifully seen in the order of the Myrtaceæ, which includes a great many species most interesting to the physiologist: while in other great woody families, such as the Leguminosæ and Rosaceæ, the quinate system completely prevails.

When a piece of wood is introduced into the fire, it burns with flame and smoke, and nothing but ashes remain, which contain carbon only united to oxygen, and saline matter. But when it is heated to the same degree, and the access of oxygen prevented, as when a piece of wood is covered with sand in a crucible, the carbon is left behind, nearly possessing the same arrangement as in the vegetable mass; for carbon is neither volatile nor fusible, and consequently the particles, during the application of the heat, do not change their place. The aqueous tissue is volatile, and escapes as water, oxygen, and hydrogen, carrying a certain quantity of carbon with them, and producing inflammable gases, fixed air, and pyroligneous acid. The carbonaceous mass which remains is a bit of charcoal. It evidently must possess a very porous structure, and is well calculated to absorb bodies which it does not repel, and which are pressed towards it, by their own weight, or otherwise, such as water and the gases. The quantity of the surrounding gaseous matter, which pure charcoal condenses within it, gives very good indications of the impatience of different gaseous bodies of the aëriform state, though not the order in which they could be compressed into liquids, for this must depend upon their relative fitness for the liquid state, as well as their impatience of the gaseous. The volumes of different gases absorbed have been carefully investigated by Saussure, and the corresponding quantity of matter (the number of particles in these volumes multiplied by their atomic weights), is expressed by the following numbers;

Sulphureous acid,	80.	These have all been condensed into limpid liquids by Mr Faraday.
Muriatic acid,	57·	
Intoxicating gas,	36·	
Sulphuretted hydrogen,	34.	
Ammonia,	33·	
Fixed air,	30·	
Olefiant gas,	24·	
Vital air,	5·9	These have hitherto resisted condensation.
Carbonic oxide,	5·4	
Nitrogen,	4·3	
Hydrogen,	1·0	

The gases thus condensed exhibit the same phenomena as when they are in the liquid state. When the pressure of their own atmosphere is above them, they do not evaporate, but when the surrounding medium is changed, they form, by evaporation, atmospheres of their own nature; and a portion of the new atmosphere is pressed into the charcoal to fill their place. They generally are given out unchanged. It appears, however, that some of delicate structure, such as sulphuretted hydrogen, when exposed to the sunbeam, suffer decomposition at the charcoal.

A mass of charcoal does not consist of individual molecules, easily capable of having their electrical state excited, like the diamond, while, on the other hand, the atomic matter of successive particles is in contact: hence it does not resist the transmission of electricity. But, in consequence of the immense number of particles which must be heated in any line in which calorific excitement is propagated, and their unsymmetrical mode of cohesion, which is unfavourable to that motion wherein heat consists, charcoal transmits heat, or is heated very slowly.

It is readily combustible, and when a lengthened mass is lit at one end, and held upwards, it becomes an electric axis, the region of chemical action being as usual positive. If it be inverted, the fumes passing along the mass restore the equilibrium, and the polarity disappears. As it does not assume the gaseous state, it cannot give rise to flame; but the light proceeding from its combustion is very intense. Every particle of carbon is, in fact, a little speculum or lens, calculated in an admirable manner to form a base to rays of light. Neither is the heat generated during its combustion by any means so great as that produced by the combustion of hydrogen; hence all circumstances are favourable to the propagation of light from the region of the combustion of carbon. The flames of candles, lamps, and gas lights, are composed of hydrogen and carbon, in a state of combustion; and the brightness and coolness of the flame, when the quantity of combustion or consumption of oxygen is the same, depends upon the quantity of carbon. The best artificial light consists of a mixture of the two gases, where hydrogen is present, in such quantity only as is necessary to give buoyancy to the carbon, and develope a sufficient degree of heat to sustain the combustion. Carbon, in small quantities, though once kindled, is apt to go out; and the particles of carbon in the diamond are so firmly bound down, that it is much more incombustible than iron and other metals. Though it be kindled in vital air, it cannot sustain its own combustion. Wood, coals, and pinguious substances, on the other hand, are admirably fitted for becoming fuel—to warm us when the hydrogen is in plenty,—and to warm themselves when the carbon is in such quantity as to render the flame very luminous, and fit for vision in the night time.

It has been already shewn, that the body which results from the combustion of the hydrogen is pure water; that which the carbon yields in similar circumstances is carbonic acid. It is generally believed to be universally the same substance as that which is derived from the calcination of limestone, or during its solution by an acid. To this the name of Fixed Air was applied by Dr Black, because it occurs in nature generally fixed with some mineral body, and not in the aëriform state. But, during combustion, another form also must certainly be developed, afterwards to be described.

Choke-damp, Fixed Air, Carbonic Acid.—Oxygen and carbon are eminently conformable to each other; and wherever a particle of oxygen (not vital air) is exposed to a free particle of carbon, they unite, and a particle of fixed air is formed (Fig. 9.), two of which constitute a symmetrical molecule (Fig. 68.) This body is generated not only in cases of deliberate combustion in the air, where animal and vegetable decompositions are going on, but also in the lungs, and apparently over the whole surface, or at least at particular regions of the skins of living organized bodies, both plants and animals. Animals provided with lungs inhale a certain quantity of air, rather more than one-fifth of which is vital air. The whole volume is again exhaled into the air, without any notable change upon its nitrogen; but a considerable part of the vital air gives its radiant matter into the system, and returns with its poles, formerly occupied by radiant matter or light, now covered by carbon. This Ζωης φως, this Φως ουρανιον, stimulates the vital energy in a very remarkable manner; and, by the aid of our knowledge of the organization of the lungs, an attempt will be made, in a subsequent page, to trace the course which the absorbed radiant matter pursues in our bodies.

The blood suffers a change of colour from modena to bright red, which is the effect that ought immediately to follow from the incidence of radiant atoms upon its coloured parts, assuming that there is no other change of organization. Let us suppose that the colour of the blood is true, and that the chromatic axis which produces it has red and blue for its positive and negative poles respectively, which are the colours perpetually recurring when transparent and colourless bodies (such as the elements of the blood are) become coloured by the institution of chromatic axes. The superficial colour of a mass consisting of such particles, will pass from bright red towards blue, according as it becomes more and more quiescent, and removed from chemical action, which determines the positive or bright red pole to that region exposed to the chemical action. If, then, the red globules set out from the lungs, each with a perfect chromatic axis, of which one pole is exposed, their colour will at first be bright red, because the surface where the chemical action is greatest will be the positive pole; but, as they proceed, this colour must degenerate, in consequence of the destruction of many of the axes, as the globules proceed from the lungs, where they were instituted, and in the process of assimilation, from the decrease of heat, and the want of chemical action to sustain a tint so highly positive. When they come up again to the lungs, after having performed the tour of the body, the mutilated axes, and the newly introduced globules, whose axes want the odd atom of radiant matter to be complete, receive the requisite atom from the vital air, and the colour of the blood is brightened again. This brightening of the colour, which seems to be thus caused by an electric change and accession of radiant matter to the blood, indicates that state which only is fit for sustaining the phenomena of life. According to the view which was advanced under Vision, this accession of radiant matter which the blood receives from the air at the lungs is equivalent to a power of secreting matter in this state, supposed in that chapter to be possessed by the nervous structure; and, therefore, the blood, as well as the nervous system, contains a quantity of sensorial matter, though here it is not, as in the other case, disposed symmetrically, or so as to be capable of constituting a continuous sensorium, and of transmitting any influence to or from the centre of the sensorial system. In the blood, the radiant matter possesses an unsymmetrical, and consequently unquiescent structure; hence it necessarily induces a tendency upon the blood to move, which motion or tendency will continue so long as a symmetrical position of the atoms is prevented. When this is permitted, all the molecules are bound in symmetrical positions, the mass gelatinizes and coagulates. The accession of this radiant matter, derived from the vital air which we breathe, stimulates and exalts the vitality of the blood; and it might be inferred, that if, during a number of respirations, a quantity of radiant matter were received into the blood, without a corresponding quantity being removed, a state of intoxication would be induced. But there is every reason to believe, that a great portion of the carbon, which is given out in a quantity five times as great as the radiant matter which is received into the system, results immediately at the common confines of the lungs, and air, from free and feculent radiant matter, carried along by the blood in its current. During the process of assimilation, and the conversion of one form into another, many atoms of matter will probably be disengaged. We must admit that calcium, phosphorus, and carbon, are immediately generated in animal bodies; for it is impossible, on the most extravagant assumptions, to explain their appearance in such quantities as are secreted or excreted in the living body by their introduction in food. Now, all these forms are composed of hydrogen and single atoms of matter, and require that, where they are developed, matter shall exist in its ultimate atoms. It has been shewn, that a particle of nitrogen may degenerate into carbon, becoming thereby a symmetrical body, by giving off five atoms of matter. It is very reasonable to suppose that, in the blood, besides its own active, symmetrical, and perfectly organized particles, there exists a quantity of feculent matter in the state of ultimate atoms. Now, the disposition of this feculent atomic matter to unite, so as to constitute the particles of bodies, must be very great, more especially as the electric states of the atoms themselves will perhaps be different, according to their positions, and the manner in which they have been disengaged. The simplest form, which they can assume is hydrogen, which, in such circumstances, is equivalent to water. After this is carbon, the evolution of which will be determined by the negative state of venous blood, and the presence of the conformable and consecutive poles of oxygen to receive it. Besides these bodies, it seems extremely probable that substances should sometimes be developed in the blood, calculated to change its organization, and of course to produce death. As will be afterwards shewn, soda and iron seem very probable, but they perhaps may not act injuriously. They are, besides, extremely dissimilar to the common organic elements along with which they are associated; hence they will increase very slowly, and will be subject to resolution. But perhaps it is to the development of substances foreign to the healthy constitution of the blood that fevers owe their existence.

Carbon and water, then, are the two bodies which we should expect to be given off from the lungs, and it seems not improbable that the former, at least, is immediately generated in the presence, and in some measure by the induction, of the oxygen which carries it off. If oxygen be not present, the matter then must remain in the blood. At first it must stimulate the system more powerfully, thus imparting to the suffocating man his astonishing muscular energy; and if fresh radiant matter be supplied at the same time, his muscular energy may be for a while sustained, and a sense of suffocation prevented. But, unless the excrementitious matter is removed as carbon, by the incidence of oxygen, death must speedily follow.

There is no other gas but vital air which can carry off the carbon; hence none beside is fit for respiration. To sustain health, it must be supplied in that quantity to which our organization is conformed. A small volume of vital air will sustain life longer then the same volume of common air, because it does not exhaust the system so speedily as to produce death; while it can supply five times as much radiant matter, and carry off five times as much carbon, as an equal volume of common air. But were the free air around us undiluted vital air, the course of life would go on too rapidly. We should not indeed be intoxicated, because, though a greater quantity of light entered the system, a proportionally greater quantity in the state of carbon was withdrawn; but the pulse would be rapid, our hours anxious and restless, and we should soon die.

Although, however, there is no other gas except vital air, which is fit for sustaining a true respiration, imparting radiant matter by its descent, and removing carbon by its ascent, there is another gas which does not injure the texture of the lungs, and which, when breathed pure, supplies radiant matter in the same quantity as vital air. This is nitrous oxide (Fig. 42.), which has been already described; it cannot easily evolve carbon, because its poles are unconformable, and its affinity for carbon indirect. Hence, while it is breathed, this gas must intoxicate, for it supplies radiant matter from without, and does not remove any from within in the state of carbon. Its intoxicating effects have excited the admiration and curiosity of chemists, and it has obtained the name of Intoxicating Gas.

Physiologists have often wondered in what way the external air, drawn down into the lungs, should be able to find access to the blood, as the air and blood are believed to be parted by an impervious membrane. But the most impervious tissue that can readily be conceived, will no doubt contain numberless minute molecules of water, if it be not wholly constituted of such a frame-work; and this tissue, though it could not transmit blood or any of its liquid parts, would suffer radiant matter, carbon, hydrogen, oxygen, and nitrogen to find a ready transmission. The quantity sent through would depend on the quantity carried off, or evaporated from the air-cell. The case is analogous to that of water filtered through a porous stone, or to the ordinary phenomena of perspiration, the quantity transmitted depending upon the quantity carried off from the outside, and speedily diminishing when the porous tissue continues clogged with a quantity of matter,—in a word, when it is suffocated.

It might be expected, other things being equal, that the activity of the vital air in the lungs would be greatest when the radiant medium to which its vital part belongs is most powerfully excited or most highly illuminated, that is at mid-day; and that it would decrease both towards morning and evening, and continue least during the darkness. Now, these results have been completely anticipated by the researches of that exquisite chemist and philosopher Dr Prout, who found that the quantity of combustion going on in the human lungs kept pace with the altitude of the sun, being greatest at noon and least during the night. Hence we see how sleep is naturally induced by darkness. Light, on the other hand, whether natural or artificial, keeps us awake, exhilarating the vital activities both by the direct action of the luminous rays on the eye, and by the descent of illuminated atoms of radiant matter into the breast.

In states of intoxication, it is also remarked by the same philosopher, that the quantity of carbon given out of the system is less than in states of ordinary composure. The free radiant matter appears by the state of excitement of the system to be sustained in a state too highly repulsive to admit of its aggregating into feculent masses, and being thrown out as carbon. Hence a combination of circumstances, and a condition of the blood and brain result, similar to that produced by intoxicating gas. In what region this vital current announces its state to the nervous system,—whether the nervous filaments give off their radiant matter into the blood, which, in cases of intoxication, being surcharged already, cannot take up any more, and thus sustains a state of vividness and tension over the whole system,—whether a great part of the radiant matter derived from the air by the lungs be not immediately deposited by the blood in the brain;—these are questions on which some light may perhaps be thrown in a subsequent page.

The quantity of vital air which is converted into fixed air in the lungs of animals every day is immense. In this way no fewer than 100 cubic inches are generated every three or four minutes by one person; and such is the quantity of carbon that is exhaled in consequence, that, if precipitated, it would amount to about one pound of charcoal every day, which is much more than could enter into the system from the carbonaceous elements of the food commonly eaten. Neither is this exhalation confined to the lungs. It has been observed even in man that carbonic acid is given off from the skin of the hands; and in many animals with simple lungs it is from the external surface of their bodies that carbon is given off in largest quantities. We should naturally conclude, then, that the quantity of carbonic gas must accumulate very rapidly in the atmosphere, for no natural process is known by which it is decomposed in larger quantities than it is generated. But if it be maintained that carbon is generated in the human body, it need not be denied that it may be resolved in the sunbeam into radiant matter, and carbonic converted in the process of time into vital air again. There must be one, and there can be only one, condition of the atmosphere which is quiescent and in harmony with the existing state of our planet, and departures from this state must be constantly corrected by those forces which determine vital not fixed air to be natural and quiescent.

It has been stated that the fixed air, or mineral carbonic acid of chemists, differs from vital air in the exterior poles being occupied by carbon instead of an atom of radiant matter.

The atomic weight of a particle is consequently 15, of a molecule 30, and the weight of 100 cubic inches must be one-third more than the same volume of oxygen (vital air without an atom in the pole), or 31 + 16.5 = 46.5 grains; and this weight ought to be found by the balance, as its atomic refractive power is the same as that of common air, and there is nothing very remarkable as to its specific heat. It is one of those gases indeed, which ought to give the most uniform results in the balance, being neither liable to the incidence of the radiant medium, nor acting exclusively upon it. Accordingly, we find that observers have never differed by one grain, upon so many, in their determinations, but have found it constantly between 47.11 grains and 46.84; and probably the former number, which is that of Sir H. Davy, is very near the truth. The gas which has given such uniform results, was always disengaged from limestone, in which it exists united to the calcareous earth.

The quantity of carbon, suspended in 100 inches of fixed air, is 15.5 grains; and there are in the same volume as many particles as there are of oxygen, or double the number in the same volume as of hydrogen, nitrogen, &c. It is commonly supposed that carbonic acid consists of vital air and carbon; hence the quantity of carbon present would, of necessity, be only (46.6 — 34) or 12.6 grains, and the ratio of oxygen to carbon in a given volume that of 2 to .75, instead of 2 to 1. Two atoms of carbon, then, according to the common view, are just equal to three of those here advanced *.

When vital is converted into carbonic air, it suffers no change of volume, but it is more easily condensed. Under a pressure of thirty-six atmospheres, it is reduced to the liquid form; and there is evidently no risk of violent compression resolving it into water, as there is in the case of vital air.

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* Hence the quantity of carbon in carbonic acid, according to the usual views of it[illegible]position, is less than that in the substance here treated of in the rati[illegible]to 1.222, by which number the carbon in analyses, when deduced fro[illegible]quantity of carbonic acid generated by the disengagement of fixed air from mineral bodies, must be multiplied to find the quantity according to the views of this work.

Carbonic gas is absorbed by water in considerable quantities, and is that gas which imparts to effervescing draughts, sparkling wines, and malt-liquors, their agreeable pungency. Its acid properties are very weak. Delicately tinted bodies, such as litmus paper, are reddened by it, but their colour is again restored when they are exposed to the air, in consequence of the natural evaporation of the acid gas. It unites with bases in quantities depending on their forms and powers of saturation; and the salts resulting are most frequently of a stony nature. It cannot be made to descend into the lungs, as it excites a violent spasm in the glottis. Where it exists so much diluted by common air that this spasm is not occasioned, it acts as a narcotic poison, speedily producing lassitude and inability to escape. Hence, being generated abundantly in many damp carbonaceous strata, it has often occasioned death to miners, and has received the formidable name of Choke-damp. Its disposition to absorption, the similarity of its form to that of nitrogen and vital air, which gives rise to a repulsion between them, and prevents their passing each other in opposite currents, and its great weight, combine to render its equable diffusion through the atmosphere comparatively very slow. It may be poured from one vessel to another like a liquid. Hence, also, it remains, filling wells, pits, caves, brewers' vats, and other hollows, in which it has been generated; and as it is invisible, individuals who have incautiously descended into such places have sometimes been choked. Others, again, who have fallen asleep on floors and low beds in close chambers, where charcoal fires were burning, have sometimes never awoke. As an atmosphere unfit for respiration is also unfit for combustion, the presence of carbonic gas in fatal quantities may be readily detected by putting down a lighted candle.

Fixed air is contained in large quantities in the soil and in manures, and appears to be a substance highly nutritive to plants. In fact, it only requires a particle of hydrogen to give origin to one of water and one of carbon, and to go directly to the aqueous and carbonaceous tissue. It occurs, also, in waters whose vital air, absorbed from the atmosphere, fishes convert into fixed air by a process similar to the breathing of land animals. It is present in the atmosphere only in a very minute quantity. The air on the summit of Mont Blanc, around those who observed it, was found to contain carbonic acid; but whether it be proper to these lofty regions, or was derived from those who collected it, cannot be immediately judged of from the circumstance that it was found there. There can be no doubt, however, that, in a sufficient time, an uniform mixture will take place between common air and carbonic acid, though the time which it requires to be penetrated by the particles of air, and ascend amongst them, be much greater than in most other cases. Thus, Berthollet found that, when volumes of carbonic acid and vital air or nitrogen were connected by a narrow tube, the acid gas, after 24 hours, was twice as dense in its own balloon as in the other; but when it was placed in contact with hydrogen, in that time its density was equal in both.

It has been remarked, however, that there is a certain constitution which is proper to the atmosphere in the existing state of the world, and if to this a certain admixture of fixed air be necessary, it will speedily be carried thither, though it could not penetrate other gases. Its tendency to move is not absolute but dependent on the medium in which it exists.

Such are some of the properties and the structure of the fixed air which exists abundantly in nature, and is commonly described in chemical works. But it is apparent that others may sometimes arise from the combustion of carbonaceous substances. It will afterwards be shown that Oxalic Acid consists of four particles of carbon and three of oxygen, arranged on a common axis; and that in Cyanogen three particles of carbon are placed on a common axis of a still greater length. Any combination whose axis is shorter than this, may probably be occasionally developed in certain experiments of combustion. We cannot avoid the conclusion that particles of carbonic acid abundantly generated from a violent combustion or otherwise, should apply themselves to each other in the nascent state, so as to generate other molecules than those of mineral fixed air. Thus two particles of fixed air might retain a particle of carbon in the cavity between them, which is conformable; and if the molecule only attained to this structure when escaping from the region of combustion, in this state it might ascend into the gasometer. Such a form is completely isamorphous with common fixed air, and none of the tests for carbonic acid would be sufficient to distinguish it. To prevent circumlocution, it may be called Citrogen, for a reason soon to be perceived. Its atomic weight is 35.

But such a gas is not completely burned or saturated with oxygen, and though it were generated during the combustion of carbonaceous substances, it could only escape farther combustion if it was developed on the confines of a region where combustion could not take place. It could certainly neither penetrate an atmosphere of oxygen, the peroxide of copper, nor chlorate of potash, without receiving oxygen on its poles.

If we suppose that it might sometimes escape with only one particle more of oxygen, then the resulting molecule would simply be a ternate molecule of fixed air, or that quantity proper to the sesquicarbonates. Such a form, however, is not symmetrical, and, in this respect, is worse than a binate molecule of fixed air, while it is no better as to the supply of oxygen to the carbon. In all cases where oxygen is supplied in abundance, and where the conditions are most favourable to combustion, a completely burned sort of carbonic gas may be expected, in which there are three particles of carbon and four of oxygen *. Such a body is perfectly analogous to that oxide of manganese generated by heat, and named the Red

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* It is a very fortunate circumstance that the ratio of oxygen and carbon, in this sort of carbonic gas, is the same as that commonly inferred to exist in all carbonic acids; for as it is almost always developed in the analytic combustion of organic bodies, the quantity of carbon, when taken at $\frac{3}{11}$ths of the addition which the potash has received in weight by absorption of fixed carbonic gas, is truly ascertained. Four particles of oxygen bear the same ratio to three of carbon, that two of oxygen do to one of carbon according to the common systems, 40 : 15 :: 2 : .75.

Oxide; and, as we shall afterwards find, the septenate molecule of carbon constitutes manganese.

It is to be remarked, however, that this gas, in consequence of its magnitude and two volumes of oxygen being implied in every particle, must certainly occupy a double volume, or contain in the same volume only half the number of particles that there are of molecules of vital or fixed air. In its production from vital air, therefore, there will be no change of volume in the latter, just as in the case of fixed air. Its production by detonation, however, is probably a rare occurrence, except, perhaps, when every particle of the gas detonated contains three particles of carbon suitably disposed for giving rise to this molecule. Such is the state of matters in cyanogen. The detonation is violent, and when it is burned with excess of oxygen, it appears that almost the whole is resolved into this gas, for the carbonic gas resulting is not much short of double the volume of the cyanogen, whereas, were the mineral fixed air generated, it would only amount to 1⅓ times the volume of the same.

The atomic weight of this carbonic gas is 55 (4 × 10 oxygen, + 3 × 5 carbon), and the weight of the same number of particles as there are of molecules of vital or fixed air in 100 inches, would be 85.25 grains (2 volumes oxygen 62 + 3 particles carbon, 3 × 7.75); and 100 inches would of course weigh the half of this, or 43 grains. But its poles are concave, and will be subject to the incidence of radiant matter, which will add something to its weight; so that, upon the whole, though it had been weighed, no very marked difference between its weight and that of fixed air could be noted. Nay, its deficiency in the equatorial region might even induce us to suppose that it was subject to the incidence of five atoms there, as is more obviously the case in cyanogen and chlorine. This would add about two grains more to its weight, so that the difference between its specific gravity and that of fixed air would be almost insensible. This body's impatience of the gaseous state, however, must be greater than that of fixed air. Like cyanogen, fixed air, and other analogous forms, it will no doubt be absorbed by potash with avidity. But probably means may be resorted to by which the carbonic gas in union may be reduced to its legitimate state, and thus a fourth part of the volume of carbonic gas absorbed be set free as vital air.

The quantity of carbon in 100 inches of the carbonic gases containing three particles of carbon, is about 11.627 grains, while in fixed air it is 15.5 grains *.

It appears, then, that the same quantity of carbon, when elevated into the gaseous state by union with oxygen, may give rise either to one and a half or two volumes of carbonic gas, according as it is disposed of as fixed air or this carbonic gas of combustion. For it is presumed that the vital air determines the density, and in fixed air there is only one volume of oxygen and two of carbon; in this again, there are two of oxygen and three of carbon. It may be possible, therefore, from the same quantity of an organic substance to raise either one and a half or two volumes of carbonic gas, according to the manipulation employed.

If these views be sound, the discordant results which mark the details of organic analyses by the most eminent chemists no longer appear anomalous. As I shall often have occasion to speak of this gas, and cannot find a name for it already applied to the carbonic gases which might not occasion mistakes, I shall call it Pyragyne or Pyragynic Acid †.

Carbonic Oxide.—When both poles of a particle of oxygen are covered by carbon, a very symmetrical icosaedral form

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* These numbers are to each other nearly in the ratio of .923 to 1.222, and as we must multiply the carbon of analyses inferred from the volume by 1.222, when that volume is supposed to be fixed air, so we must multiply it by .923 when the gas evolved is supposed to be this sort of carbonic gas. The quantity of carbon commonly supposed to exist in carbonic acid, is about equal to a mixed atmosphere of the two carbonic gases, of which six volumes are of the tricarbonated sort and one of fixed air. Hence analyses, when inferred from the volume, are sometimes not far from that which is here supposed to be the truth.

† Πυρα γιν-ατο, strue ligneorum igne subjecto natus est.

(Fig. 69,) results, which is the gaseous oxide of carbon, and is the first of a series which form the radicles of hydracids. Its atomic weight is 20. Its specific heat and refractive power are much the same as those of nitrogen. Its quantity of matter and density are the same; hence the weight of 100 inches ought to be the same, or nearly 30 grains, and this is found by experiment. It possesses a somewhat disagreeable odour, and burns with a thin blue flame, being thereby resolved into fixed air. To effect its conversion, every particle requires one of oxygen; and, therefore, a volume of the combustible gas requires half a volume or an equal number of particles of vital air, which disappears entirely, and as many molecules of fixed air are produced as there were particles of carbonic oxide. These phenomena may be produced by the electric discharge, which has the power either of decomposing or recomposing carbonic oxide. If a volume of the oxide and half a volume of vital air be mingled, and treated with electricity, there results only one volume, which is all acid. If, again, a volume of acid be treated in the same way, there arises a volume and a half; the former oxide, and the latter vital air. This gas is not known to be given out during natural processes, being, as we shall presently find, always engaged when in a disunited state, with hydrogen. It is isamorphous with a particle of nitrogen, as we have supposed it to exist when first developed in the animal system, and contains the same number of atoms of matter. It is the characteristic form in the most nutritious vegetable substances; and one of the effects of animal assimilation seems to be to impart unity to it, so that it shall expand when set free at the equator, and, instead of a compound combustible gas, constitute a quiescent binate molecule of nitrogen. Carbonic oxide seems to escape during the puddling of iron. For the purposes of experiment it may be procured by deoxidizing every other particle of nascent fixed air, or by disengaging it from chalk in the presence of iron. It is also obtained from oxalic acid, into whose composition it enters as a constituent part.

Acetic Acid.—Carbonic oxide is analogous in its structure to a class of bodies, which receive hydrogen on their poles, and constitute hydracids. These hydracids appear to be very abundant in the products of organization, and we should infer that none possesses so simple a structure as acetic acid.

Wherever green farinaceous or saccharine vegetable matter is exposed, in a state of solution, to a warm temperature and the open air, it is apt to ferment, and to become vinegar. The acid particle which imparts to vinegar its sourness and property of dissolving limestone, is composed of a particle of carbonic oxide, with one of hydrogen on one pole, (Fig. 70).

Acetic acid is also formed in the living vegetable tissue, and remains in union with lime or potash. At the period of drying up, and decay of the vegetable structure, it appears to be developed in a free state, and to give rise to the acid tints that precede the fall of the leaf. It is also abundantly formed in the destructive distillation of wood. From this source, the Pyroligneous or Pyroxylic Acid, or Wood-vinegar of commerce, is derived, and it is chiefly to its presence that burning wood owes those pungent fumes which act so powerfully upon the eyes Acetic acid is a form of very great delicacy, in consequence of the vicinity of its hydrogen to its oxygen, and their existence in the quantity requisite to form water. If it could be procured free from water, it would doubtless be an inflammable gas, and, at a certain temperature, spontaneously explosive. When united to water, in which state only it can be obtained, it is, in its most concentrated state, a very pungent volatile liquid, having power to disorganise the skin. Its vapour is combustible, yielding water and carbonic acid.

The atomic weight of a single particle is 22, (10 carbon + 10 oxygen + 2 hydrogen). Its carbon and oxygen are equal in quantity, and after spontaneous destruction, it would be resolved into water, and 45.5 per cent. of residuary charcoal. These proportions of its constituents have been determined with precision by Berzelius and Dr Prout. Berzelius states its carbon 46.82, and oxygen 46.83, and its hydrogen very nearly twice the volume of its oxygen, or in the proportion to form water; and Dr Prout has shewn, that its oxygen and hydrogen are exactly in that proportion.

But acid in the state of insulated particles cannot be obtained; for the acid, when disengaged from combination with a base, is always united to water; three particles, as usual, being fixed around the equator of a particle of water. The quantity of acid in this hydro-molecule is 66, of water 12; and in the salts which acetic acid forms, it very often enters into union in these ternate hydro-molecules. Its salts are of a very imperfect kind, and are very difficultly elevated into the crystalline state.

The acid itself in the state of hydro-molecules, is capable of assuming the crystalline state, at temperatures under 10° cent. or 50° Fahr.; and this applies also to another hydro-molecule, more fully charged by acid than the ternate. For it is only to be expected that the dexterity of chemists should be able to insert another particle of acid in the pole of the central particle of water, and thus to give rise to a quaternate hydro-molecule, in which the ratio of the acid to the water is 88 to 12, or 100 to 13.6. Now, the strongest acetic acid is said by Thenard to contain 12.5, and by Mollerat, 14.75 of water on 100 of acid, the mean of which is the true ratio, or 13.6 on 100 of acid.

We found that the oil of vitriol, in which the greatest condensation occurred, was that in which the two naked poles of the sulphur in every particle were covered with water, and when there was no more. Here, there are in every molecule three naked poles, conformable for the reception of water, and the greatest density ought, for a like reason, to occur when they are supplied, and there is no more, that is, when the number of particles of acid to water is 3 to 4, or 66 to 48. Now, it has been shewn by Dr Thomson, that the acid of greatest density contains acid 62.5, and water 45, which are in the ratio of 66 to 47.5. When three additional particles of water are attached, another hydrated molecule occurs. Its atomic weight is 162, or about double that of the molecule of

78. But supposing their equators arranged symmetrically in the same plane, and the spaces between them equal, then the number of particles of the heavy molecule in the same area, compared with those of the other, would be as 4 to 9 nearly.

When three other particles of water are added, so as either to occupy the three intervals on the equator of the central particle, or, if this was the position chosen by the former three, to occupy the intervals between the three particles of water which are upon the poles of the hydrogen, and to produce a senate molecule, the acetic molecule is completely hydrated; and it is probable that such are the molecules which, dissolved or equably diffused in water, constitute vinegar. The number of aqueous particles in each is 10, and the atomic weight is 198.

Citric Acid.—When treating of carbonic gas, a substance was distinguished under the name of Citrogen, which consisted of a solid molecule, isamorphous with a binate molecule of fixed air, but differing by the accession of a particle of carbon into the hollow which exists in the centre of a molecule of fixed air. It appears that when a particle of hydrogen is incident on the pole of this body, it constitutes a particle of Citric Acid, (Fig. 71). A particle of this acid, then, may be regarded as a particle of acetic acid, with one of carbonic acid on its carboniferous pole. The atomic weight of citric acid, according to this view, is 37, (15 carbon + 20 oxygen + 2 hydrogen), and the proportions of its elements are stated exactly by Berzelius and Dr Prout. The analysis of Berzelius gives equal volumes of hydrogen and oxygen, that is, one particle of hydrogen, and two of oxygen; and the ratio of the oxygen to the carbon is stated at 54.83 to 41.37, 54.88, and 41.12, being the true ratio. The analysis of Prout is still more exact. The constituents are stated in carbon, water, and oxygen, for which there is no hydrogen. Now, there is one particle of oxygen, for which there is no hydrogen, and there are only two; hence the quantity stated by Prout as oxygen, must be doubled. This gives the ratio of 34.28 carbon, and 45.74 of oxygen, the true ratio being 34.28 and 45.706!

The particle of citric acid is too large for forming in ternate molecules with a particle of water. Dr Thomson assigns the equivalent of a particle of water to every one of the acid (which would just cover its hydrogenous pole), as the constitution of the crystals examined by him. It appears, that, in these vegetable crystals, the quantity of water involved is sometimes very variable. But it is easy to conceive how one hemisphere of a crystallizing molecule could be formed, if one particle of acid in the centre were surrounded on its equator by five, the number demanded by its quinate form, each of which had a particle of water on its pole. In this case, the influence of the surrounding water causes the central particle to retain its water with a weak affinity, and to part with it either on entering the crystalline state, or during subsequent exposure. Such molecules, in which a particle of the acid or base form a nucleus, are not uncommon, and such appears to have been the crystallizing molecule examined by Berzelius. Its atomic weight is 282 (222 acid + 60 water); and it contains 79 per cent. real acid, as stated by Berzelius.

There is yet another crystallizing molecule. By the cautious application of heat, ⅓d of the water in that more fully hydrated is given off, and there remains a ternate molecule of water to six particles of acid. Now, though the rude manner of driving off the water by heat causes the crystals to fall down in powder, an arrangement may be instituted between them in these proportions, which is highly symmetrical and analogous to that which obtains in the bicarbonate of ammonia. The ternate molecule of water occupies the centre, and the six particles of citric acid are distributed in three pairs upon the most distant edges, which are adjacent in pairs. If three such molecules are again united by a particle of water, a nearer approach to quiescence will be effected, and such is almost exactly the quantity of water and acid in the crystals of Dr Prout. The quantity of matter stated as water in his analysis, amounts to 42.85 per cent. From this, as we have seen, a particle of oxygen, which it appears from the analysis is equivalent to 22.87 per cent., and a particle of hydrogen, which is the fifth part of 22.87 or 4.57, are to be subtracted, so as to leave the real quantity of water. This amounts to 10.1 particles to 18 of the acid, that is, three particles to each of three senate molecules, and a particle in the centre to unite them.

Oxalic Acid.—By the addition of another particle of carbonic acid to citrogen (or the base of the citric acid), it becomes Oxalic Acid, (Fig. 72.). But now, in consequence of the great length and solidity of the axis, it seems to become unfit, at least when exposed to heat and in a state of combination, to entertain a particle of hydrogen on its pole. The atomic weight of oxalic acid is 50, (4 × 5 carbon + 3 × 10 oxygen); and in those cases in which its pole is hydrogerent, its atomic weight is 52, and the absolute weight of the hydrogen is less than 4 per cent. It is very easy to conceive the conversion of oxalic acid, by the aid of oxygen and heat, into fixed air. One particle, by expansion and contact with one particle of peroxide of copper, is converted into two of fixed air. For its conversion into pyragyne, three of acid and seven of oxide would require to be simultaneously decomposed, from which four particles, or eight volumes of pyragynic gas, would escape. To effect this, compression and violent deflagration would perhaps be required. In the analyses of Berzelius, Prout, and Thomson, fixed air, therefore, seems only to have been generated. They all very nearly agree with each other. That of Berzelius gives carbon 33.22, and oxygen 66.53. To find the true quantity of carbon, supposing fixed air generated, the carbon must be multiplied by 1.222. Now, $33.22 \times 1.22 = 40.52$; and the quantity added to the carbon must be taken from the oxygen or vital air. But $66.53 - (40.52 - 33.22) = 59.2$; so that the carbon and oxygen are severally 20.26 and 29.6, the ratio proper to the structure here advanced being 20 to 30. The analysis of

Prout gives the carbon and oxygen as 20.2 to 30; and that recently by Thomson 20.5 to 30.

It is difficult to conjecture what may be the form of the crystallizing molecule of this acid, supposing it without hydrogen. We learn, from observation, that it is not perfect, for the crystals effloresce when exposed to the air. It appears, from experiment, that every particle is, in some cases, associated with a ternate molecule, and that, in other cases, there are three particles of acid to four ternate molecules of water. In the former case the crystals contain about 42, and in the latter about 49 per cent. of water.

Oxalic acid, according to the structure here assigned, evidently consists of an equal number of molecules, or volumes of fixed air and carbonic oxide, and into these it will be resolved by a simple expansion of the axis. This effect is produced by heating the acid with strong oil of vitriol, and this is one of the methods employed for obtaining carbonic oxide.

Oxalic acid does not occur so abundantly as the former acids, after developing which, the union of carbon and oxygen on a common axis is usually arrested. It is probable, indeed, that oxalic acid is never generated in a free state; but when citric, carbonic, or acetic acid, has united in single particles, with large atoms, such as potash or lime, particles of carbonic acid are successively added, till the salt become an oxalate. United to potash, this acid is met with in the sorrels, the *Oxalis acetosella*, and other acidous plants. It is also held in solution in the urceolate appendages of the leaves of that very interesting plant the *Nepenthes distillatoria*. United to lime, it constitutes a considerable part of the fronds of certain crustaceous lichens. With this base, it forms a stony body as insoluble as limestone itself, and in a state of such quiescence, that it cannot easily be decomposed. Oxalic acid is a poisonous substance, and from being used in the arts, and from the general resemblance of its form to that of Epsom salts, in the hands of careless apothecaries it has frequently occasioned fatal accidents.

Tartaric Acid.—It will be afterwards shewn, that, during the conversion of saccharine and amylaceous matter into alcohol, a large quantity of carbonic acid gas must be given off. During the rapid period of the fermentation, this escapes into the air, but it also unites among its own particles in the liquid, especially when aided by potash, and Tartaric Acid results. The bitartrate of potash, thus formed, is deposited in the cask, and forms that well known precipitate from wine, named Tartar. The method of the development of the tartar is highly analogous to that of nitre, afterwards to be noticed. The end to be attained is a body permanent in the air, in the case of nitre, and permanent in the water in the case of tartar. It will be afterwards shewn, that potash is a beautiful quinate form, of great power, with five parts around its circumference, which naturally demand in the acid, with which it is united, five particles of oxygen to correspond to them. That such is the arrangement in nitric acid (Fig. 41.) has been already shewn, and the phenomena of tartaric acid lead us to suspect that it possesses a similar structure. Without entering into the details of its development in wine casks, which would imply a knowledge of the structure of potash, it may be stated, that tartaric acid, in the free state, seems to consist of six particles of carbonic acid, five being arranged around one in the centre, which has a particle of hydrogen on each pole. The atomic weight of this acid is 94, (6 × 5 carbon + 6 × 10 oxygen + 2 × 2 hydrogen).

Another view, however, may be taken, which accords better with analysis, by affording another particle of hydrogen. We may suppose that there is only a particle of carbon in the centre, with a particle of hydrogen on each pole, one of them, as usual in such cases, sustaining a particle of water, into the pole of which the hydrogen is inserted. According to this view, a hydrated particle is equivalent to three of hydrogen, six of carbon, and six of oxygen. This corresponds to the atomic structure assigned by Prout and Thomson, four particles of carbon, according to their views, being equivalent to six of this work.

The structure of the tartrates, however, is more favourable to the former idea; and as to the hydrogen in such acids, there is every reason to suppose that, like the radiant matter itself, it varies in quantity. It is presumed, according to the former view, that tartaric acid, when set free from combination, imparts greater solidity to its axis, and neutralizes the carbon on its pole, which, in such a situation, is far more powerful than when free, by decomposing a particle of water. In the free state, as has been assumed, this decomposed particle of water remains on the pole. But when the acid enters into union with bases, whose combining regions are conformable to the carbon on the pole, now hid under the oxygen and hydrogen, the water is again recomposed, a permanent salt is formed, the acid part of which consists of six particles of carbon and five of oxygen, its atomic weight, including one particle of hydrogen, being 82; while the water is discharged or occupied in the crystalline form, as the case may be. This double form which water may assume, according as it must accommodate itself to a quinate or ternate body, is of frequent occurrence, and has already occupied the attention of chemists in the phenomena of chlorides and cyanides.

It is remarked of tartaric acid, that it yields, during destructive distillation, more pinguious products than most other acid bodies. Nor will we wonder at this, when we consider how much exposed the naked poles of its oxygen are to the incidence of hydrogen. In consequence of this, water must be generated; and the carbon set free, uniting with the hydrogen, will produce oily matter. Were the particle of hydrogen in the centre to be attracted to one of the concave poles of the oxygen which surround it, and to be engaged along with it in forming water, the central particle of carbon along with that set free, and the particle of hydrogen not yet disposed of, would immediately be developed in the ratio of olefiant gas *. Besides during the preparation of wine, this

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* The model of the acid now described is very beautiful, but I have not figured it, as it is difficult to conceive it by the use of mere lines.

acid is also developed in certain fruits, of which the grape is one, and the tamarind another. It possesses an agreeably acid taste, and enters into the composition of some valuable medicines: it is also employed in the arts, being procured in sufficient quantity from the tartar deposited in wine casks.

Malic Acid.—There is yet another vegetable acid which performs a very important part in the maturition of fruits, and which is very abundantly developed in nature. It occurs in the pulps of the fructification and even in the foliaceous tissue of succulent plants, such as the *Sempervivum tectorum*. It has been extracted for chemical examination from the *Sorbus aucuparia* or Mountain-ash, and has been described as sorbic acid; but, as it abounds also in the fruit of the apple, and other notable fruits of that class, it is more generally known by the name of Malic Acid. It cannot, like the other vegetable acids that have been noticed, be exhibited in the crystalline state; and, though its taste is intensely sour, its salts are not possessed of any interesting chemical properties. That with the oxide of lead, however, forms brilliant crystalline plates.

Our chemical knowledge of it is very imperfect. It is probable, indeed, that there are as many malic acids as there are sugars, and the quantity of hydrogen may be very various.

The circumstances in which it is developed in nature, and during the decomposition of sugar, as will be afterwards noticed, awake the presumption that it consists of two ternate hydro-molecules of acetic acid, having three particles of hydrogen common to them, instead of six, which exist in the two when separate; and the analysis of Dr Prout agrees with this structure. In other cases it may consist of two ternate hydro-molecules of acetic acid adhering together. Fig. 73 represents the malic particle on the first supposition, there being three such, and two particles of water in every particle of malic acid.

The atomic weight of malic acid, according to this view, is 150 (12×5 carbon, $+ 6 \times 10$ oxygen, $+ 3 \times 2$ hydrogen, $+ 2 \times 12$ water). Estimated in carbon, oxygen, and hydrogen, it yields 60 carbon, 80 oxygen, and 10 hydrogen. The analysis of Dr Prout, stated in these elements, is carbon 40.68, oxygen 54.24, and hydrogen 5.08; those arising out of the structure here assigned, being carbon 40.68, oxygen 54.26, hydrogen 6.78. Dr Prout observes, that "this acid, in many points of view, may be regarded as one of the most interesting and important of all the vegetable acids,"—a remark which, if the view of its structure here advanced be sound, indicates the penetration of a philosopher, whose eyes are directed to nature, while it will not be disputed that his hands have worked out some of the most exquisite analyses of the laboratory.

It will afterwards be shown that alcohol, sugar, and malic acid, are related to each other, as a base, a carbonate, and a bicarbonate. Previous to pursuing this train of forms, however, it is convenient to notice some of the most simple compounds which carbon makes with ammonia and hydrogen.

The acid bodies which have been examined, may be thus expressed, the water of their structures being disregarded:—

	Carbon.	Oxygen.	Hydro.	Weight.	Carbon.	Oxygen.
Pyragynic acid, .	3	+ 4		= 55	= 100	+ 266.6
Fixed air, . . .	1	+ 1		= 15	= 100	+ 200.
Tartaric acid, . .	6	+ 5	+ 2 ?	= 84	= 100	+ 166.6
Citric acid, . . .	3	+ 2	+ 1	= 37	= 100	+ 133.3
Oxalic acid, . . .	4	+ 3		= 50	= 100	+ 120.
Acetic acid, . . .	2	+ 1	+ 1	= 22	= 100	+ 100.
Malic acid, . . .	4	+ 2	+ 1	= 150	= 100	+ 100

The Volatile Salts. Carbonates of Ammonia.—Ammonia unites with fixed air, and several salts are produced, of interesting characters. As the acid is a small quinate form, it cannot find access to the poles of the ammonia, which is ternate, and externally isamorphous, with a double molecule of water. It must therefore be distributed, as usual, around the equator on its alternate segments. We should expect, then, that the most natural and common carbonate of ammonia, viz. that which is used as a stimulant in faintings, &c., should consist of one particle of ammonia and three of fixed air. Such is known to be its structure. It has been named a Sesquicarbonate, which is equivalent to a tricarbonate of this work. There is also a particle of water present, so that its atomic weight is 83 (26 ammonia + 3 × 15, fixed air + 12 water). In consequence of ammonia being $\frac{1}{9}$th lighter in the gaseous state than its true weight, analyses generally give its atomic weight as 23, instead of 26. Dr Ure's analysis of this substance, however, is as follows:—

	Dr Ure.	True ratio.
Acid,	45	45
Ammonia,	25.2	26
Water,	12	12

This white crystalline substance is procured by the distillation of the excrementitious parts of animals, such as horns, hooves, camels' dung. At first it has a crystalline appearance, is hard, compact, and translucent; but when it has been for some time exposed to the atmosphere, it loses weight, its pungent odour and transparency degenerating into an opaque friable mass. During this process it is improving its symmetry by letting go into the gaseous state every third particle of water and ammonia, charged with one of fixed air, so that the resultant form consists of a senate molecule of water, surrounded by six particles of ammonia, each of which is charged with four particles, or two molecules, of fixed air, symmetrically opposed to each other, and, along with the particle of water attached to each, sustaining a senate arrangement. This is a permanent form, which may be made to crystallize in six-sided prisms. Every particle contains 60 fixed air, 26 ammonia, and 12 of water. It corresponds to equal volumes of fixed air and ammonia; but the gases will not combine in these proportions, for, without water, a ternate arrangement cannot be instituted. They readily combine, however, in the proportion of half a volume of the acid gas, and a whole volume of the alkaline. The ratio of equality of molecules is too simple to be resisted, and six such immediately give rise to a crystallizing molecule.

Thus, there are no fewer than four carbonates of ammonia.

1. That which escapes into the air from the volatile salt of

the shops, and consists of a particle of each, and whose atomic weight, disregarding water, is 41.

2. The carbonate of chemists, which consists of a molecule of fixed air and a particle of ammonia; disregarding water, its atomic weight is 56.

3. The volatile salt of the shops, which possesses the ternate and natural arrangement, consisting of three particles of acid and one of ammonia; its atomic weight is 71.

4. The bicarbonate, or tetrocarbonate, whose atomic weight is 86.

Carbon and Hydrogen.—We have seen that the compounds of carbon and oxygen, or those in which oxygen predominates, constitute meagre acidous bodies, which perform a very important part in the vegetable, and also, it may be added, in the animal economy. Those which result from the union of carbon and hydrogen are not less important; but they are pinguious and oleaginous inflammable bodies, not found circulating in the sap, but rather in the ultimate regions of the vegetable, such as the lengthened cells (named proper vessels) of the bark, and in the cotyledons of the seed. The function of the vegetable economy, then, subordinate to those which consist in the evolution of the vegetable form itself, is to separate burned bodies into their inflammable constituents again, and out of aqueous and acid particles to generate such as are oily and inflammable. These may be regarded, in a great measure, as excrementitious, in as far as the parent plant is concerned. The intermediate production in which the elements of both are locked up for the future exigencies of the plant, is starch or fecula.

The compounds of hydrogen and carbon are volatile odorous bodies. Some of the artificial compounds of the chemist make a very near approach to the camphors, spermacetis, and other inflammable products of organization; but it cannot be said that any organic molecule has yet been produced in the laboratory from inorganic elements. The mechanism of organic molecules is too delicate, and their magnitude too great, to admit of their being constructed during the momentary unions and decompositions of the chemist. The number of gaseous compounds of carbon and hydrogen, in individual particles, is perhaps not less than four, one containing five particles of hydrogen round one of carbon, and another with a particle of hydrogen on each pole of one of carbon. Nay, a form in which both these are united, and which consists of a particle of hydrogen on every solid angle of one of carbon, seems not impossible. But whether such particles are ever formed or not, there are only two, of the simplest possible structure, that are possessed of much interest.

Fire-damp. Light carburetted Hydrogen.—This gas consists of a particle of hydrogen on the pole of a particle of carbon (Fig. 10). It is abundantly disengaged from stagnant pools, from strata of coal, and volcanic chasms. It is also generated abundantly during the distillation of pit-coal, forming one of the constituents of coal-gas, and during the destructive distillation of carbonaceous vegetable matter. One particle of it united to one of carbonic acid, forms a particle of dry pyroligneous or acetic acid; and besides pyroligneous acid, various compounds of carbon and hydrogen, probably an oxycarburetted hydrogen, consisting of a particle of hydrogen on the carbonigerent pole of one of carbonic acid, nitrogen, and steam, are all given off during the distillation of wood.

Light carburetted hydrogen is readily distinguished from hydrogen by its brighter flame, its greater weight, and the products of its decomposition. It has been shewn, that, both in carbonic acid and carbonic oxide, there are as many particles of carbon in a given volume, as there are in the same volume of vital air. Carbon, which does not, without extreme difficulty, assume the gaseous state, perseveres in this degree of density in many of its compounds, in a very remarkable manner. In this gas two particles may be considered as necessary to form a symmetrical molecule, and of these double particles, there is, in a given volume, an equal number, as in an equal volume of vital air. But we shall afterwards find, that in symmetrical particles, such as olefiant gas, there is still the same number of particles of the gas in a given volume, as of particles of vital air. Hence light carburetted hydrogen requires double its volume of vital air for its combustion, every particle of the inflammable gas evidently requiring a molecule of the supporter. There results one volume of fixed air, equal to that of the inflammable gas, and the other volume of vital air takes down all the hydrogen as water. This combustion is accompanied by a violent explosion, and the same occurs when the gas is inflamed in common air. Hence the accidents which frequently happen to miners. When the carbon is disengaged from the hydrogen, and thrown down, the latter of course expands, so as to occupy twice its volume when engaged with the carbon. The exclusive power of the hydrocarbonaceous gases upon the radiant medium is very great, arising partly from their double density, and partly from the high refractive power of their elements. Neither are they in any degree subject to union with accidental atoms; hence their weight indicated by the balance is less than that which expresses their true specific gravity. It seems to follow, that when radiant matter is excluded, it shall be in sets of atoms, corresponding to one, two, or four, for every particle of the gas, thus rendering 100 inches lighter than the truth by 1.5 or 3 or 6 grains. In the cases of strangely formed particles, however, such as the aëriform compounds of sulphur and hydrogen, perhaps these numbers of symmetrical exclusion do not obtain. Were the condition of carburetted hydrogen the same in respect of the interlaced radiant matter as common air, 100 inches ought to weigh (15.5 carbon + 4.2 hydrogen) 19.7 grains. The experimental result is only about 17 grains, indicating that an atom of radiant matter is excluded by every particle of the gas, or that it is lightened nearly 3 grains. The atomic weight of the gas is 7. By itself it does not possess symmetry, nor does it seem, in an uncombined state, to perform any important functions in nature. A particle of hydrogen is more justly charged with carbon, when there is a particle of the latter on each pole of the hydrogen. This constitutes

Olefiant Gas.—This gas (Fig. 11), is generated during the distillation of bituminous bodies, which burn with a bright flame, such as cannel coal and fixed oils. It may also be procured from ether and alcohol, which it constitutes along with water. It is a most valuable ingredient in substances used for the purposes of illumination, as it is better suited for giving out light than any in which hydrogen is more abundant, while the heat which it generates is fully adequate to sustain its vivid combustion. “The particles of olefiant gas are as numerous in a given volume as those of vital air, or twice as dense as hydrogen. Hence, when the carbon is thrown down, as in the former case, the hydrogen expands to twice the volume of the gas destroyed; one volume requires three of vital air for combustion, and two of carbonic acid result. “Every one of its three constituent parts requires a particle of vital air. There are three parts in every particle of the olefiant gas, and twice the number in the same volume as there are molecules of vital air. Hence every volume requires six particles, or three molecules or volumes of vital air, a third part of which falls with the hydrogen as water. If the hydrogen could be replaced by oxygen, carbonic oxide and pure hydrogen would result. The number of particles of each would be as great as those of olefiant gas; and as each of these gases occupies a double volume, compared with olefiant gas, one of olefiant gas, by such a change, would be expanded into four. Notwithstanding the difficulty of preventing the combustion of the hydrogen, or its union with the oxygen to form water, Sir H. Davy succeeded in this way in expanding one volume of olefiant gas into three and a half of carbonic oxide and hydrogen.

The quantity of carbon in this gas is double that of the former, and every particle seems to exclude a double quantity of radiant matter, or two atoms to every one of the pinguious gas; so that 100 inches are nearly six grains lighter than the weight which would express the true specific gravity. This weight is (15.5 × 2 carbon, + 2.1 × 2 hydrogen), 35.2 grains; and it has generally been found to weigh about six grains less, or between twenty-nine and thirty grains. Hence it is evident that, in converting a quantity of alcohol, ether, or oil, into olefiant gas, the volume obtained must be considerably less than the weight of the materials would lead us to expect, or there must be a loss of weight when the matter is thrown into the gaseous state. But if a volume much larger than 100 inches were weighed, probably it might be found to possess a higher specific gravity than that inferred from weighing small volumes, as is commonly done.

Binolefiant Vapour.—When a mixture of olefiant gas and carburetted hydrogen is violently compressed, the particles of the former are subject to adhere together in pairs, producing a substance which has been described, but not named, by Mr Faraday. Below the freezing point it remains a liquid, which is lighter than any other. The specific gravity of the vapour is about twice that of olefiant gas, and burns with a brilliant flame. Every volume requires six of vital air for combustion, and four of carbonic acid result. These facts indicate that it consists of two particles of olefiant gas adhering together.

Olefiant gas is somewhat impatient of the aëriform state, and readily enters into union with many bodies. It does not occur in nature in the gaseous state, but is a very active agent in the animal and vegetable economy, being found united with oxygen and water, producing many very valuable bodies, such as sugar, starch, ardent spirits, ether, and fixed oil.

Sugar.—The sap of plants consists, in a great measure, of pure water. The first vegetable product which usually appears in it is sugar. It belongs to that part of the circulation which has not been exposed in the leaves to the air and the sunbeam, from which there result pungent, odoriferous, volatile, and highly inflammable bodies. Saccharine matter is abundantly developed in the ascending sap, previously to the expansion of the leaves, and seems, in its simplest forms, to be that body which immediately results from the resolution of starch, the reproduction of which, next to the development of the individual, is the end to be attained in the vegetable nutrition.

There are many different sorts of sugar, differing in their flavour and chemical properties, according to the organic structure in which they are produced.

The saccharine principle (Fig. 74.), in its most mature form, consists of a particle of olefiant gas united to one of fixed air, or one of carbonic oxide united to one of carburetted oxygen; and a particle of sugar consists of two particles of water bound together by three such bodies, the edges of the carbons in the olefiant gas being applied, as usual, to the alternate edges of the equators of the two particles of water. The molecule which results possesses much stability, and is capable of chemical activity.

Its atomic weight is 105:—

Carbon, . .	$9 \times 5 = 45$
Hydrogen, . .	$3 \times 2 = 6$
Oxygen, . .	$3 \times 10 = 30$
Water, . .	$2 \times 12 = 24$
	105

One hundred parts contain 42.85 carbon and 57.15 of water, or of oxygen and hydrogen in the proportions to form it, which are the very numbers afforded, by the analysis of Dr Prout, for the best cane sugar!

Sugar agrees somewhat with alkaline bodies, rendering oils miscible with water. It possesses some very interesting chemical relations. By digestion with nitric acid, its structure is destroyed, and its carbon occupied as oxalic acid, which is so intimately related to this form, that it requires only a particle of oxygen to unite two of carbonic oxide, so as to constitute a particle of oxalic acid. But while the saccharine matter degenerates into water and oxalic acid, on the one hand, the symmetry of other particles is elevated by the incidence of three of oxygen and three of carbon; that is, three of carbonic acid upon the particles of carbon, which are exposed on the summit of the hydrogen. In this way the particle of sugar becomes symmetrical on both sides of the centre or equator, receives an accession of 45 to its atomic weight, and is known by the name of Malic Acid. The oxalic acid, by evaporation, may be withdrawn in the crystalline state, but the malic acid, being incapable of assuming the solid form, remains in the mother water. Such are the interesting phenomena which accompany the treatment of sugar with nitric acid. But it requires an oxygeneous menstruum far stronger than those that occur in nature to change sugar plentifully into oxalic acid. Its tendency is evidently, by breaking up, to give rise to acetic acid. In fact, as soon as one particle of sugar separates at the centre, two forms are immediately developed; one of which is a perfect ternate molecule of acetic acid; and the other, a particle of water, with three of carbon on the alternate segments of its equator. The latter is a form which cannot exist if the access of oxygen is permitted. In that case, every such particle gives rise to three of carbonic acid, which escape as gas, occupying a volume equal to that of the oxygen absorbed from the air. There remains, then, from the acidous fermentation of every particle of sugar, a hydro-ternate molecule of acetic acid, and a particle of pure water, three particles of carbon being given off as fixed air. To effect the separation of the sugar into two parts a considerable temperature is required, and the resolution is greatly aided by the presence of yeast, to ascertain the structure of which will be a high achievement.

As soon as the saccharine particles are torn asunder, the acetic acid is developed; and therefore the access of air is not necessary to develope acetic acid in a saccharine vegetable infusion, but it must be necessary to remove the feculent matter, and give rise to pure vinegar.

Starch.—When saccharine matter is prevented from degenerating, and yet not excluded from change, as when it circulates in the living organization of the vegetable, it rises into a more quiescent substance, which constitutes the chief nutriment of the embryo of plants during germination, of the human species, and all granivorous animals. It is known by the name of Starch or Fecula. It consists of a multitude of highly transparent globules, which are found aggregated in little clusters, in connexion with the fibres that traverse the walls in the cellular tissue of plants. They are abundant in all those regions whence vegetation is to be developed, as in the young pith at the origin of buds, in tubers, and in the seeds, either in the cotyledons, or aggregated in sacs by themselves, constituting the albumen of botanists. In cold water and alcohol starch is insoluble, and in its permanency and unfitness for being insect food, it resembles a crystalline body. But when heat is applied it speedily changes its character, and in hot water it becomes a transparent jelly, agreeing in many of its characters with the mucilage or gum which exudes from many trees. From this state it cannot again be recovered in the form of natural grains of starch.

Starch, or the amylaceous principle, is procured from many plants that are natives of all climates. In temperate regions, wheat and the potato yield the largest quantity for human sustenance. But sago, tapioca, arrow-root, and other productions of tropical climates, do not essentially differ from the former. Like different qualities of sugar, they are more or less perfectly evolved, but there does not appear to be any specific difference either in their chemical or natural qualities.

When we consider that in sugar there are only three saccharine particles on the equator of the double particle of water, while there are six areas capable of accommodating them, we should expect another form, containing six to every double molecule of water. This form would bear to sugar, as we shall afterwards find, the same relation that ether does to alcohol, and the carbon would be about 48 per cent. Its atomic weight would be 186. It seems very probable that this is a particle of starch, and six such around a senate molecule of water, would contain about 45 per cent. of carbon; and if these were united into those little masses in which starch naturally occurs by particles of water again, the carbon would be proportionally reduced. But if we suppose, as is most probable, that there is a double senate molecule of water in the centre, the carbon per cent. is reduced to the same amount as in sugar; and, by a simple separation or solution, and equable distribution of the saccharine elements, every molecule would give rise to twelve of sugar. The atomic weight of this molecule is 1260, of which 540, or 42.85 per cent. is carbon. Should this be the structure of starch, we see with what propriety it is regarded by Dr Prout as a merorganized form. Its nucleus consists of two parts, which are embryos of the aqueous tissue. There is carbon enough to produce nine spires of the carbonaceous filament; and the hydrogen restrained from the oxygen in the saccharine particles of the circumference must give rise to mobility, or a disposition to change.

Alcohol.—Sugar cannot be regarded as a quiescent body. The equators of the two particles of water are not equally charged. In one of them there are three particles of carbonic acid, which are not on the other.

It has been already shewn that, in certain circumstances, as to temperature, and when the access of the air is permitted, a solution, containing saccharine matter, is changed into vinegar, by the breaking up of the saccharine molecules, and the separation of the two particles of water. From this a very symmetrical body results, that is, a ternate molecule of acetic acid, which speedily becomes changed by nine particles of water.

But in other circumstances the sugar can effect the evolution of a perfectly symmetrical form without breaking up. For it is evident, that if every particle give off three of carbonic acid, there remain two particles of water united by three of olefiant gas (Fig. 75.). This is a particle of alcohol. Its atomic weight is 60 (36^3 olefiant gas, 24^2 water). For every particle of alcohol generated from sugar, three of fixed air must escape. The quantity of fixed air and alcohol together must be equal to the weight of the sugar employed, and their ratio must be 60 alcohol and 45 fixed air, or 57.2 and 42.8 per cent. Now, Saussure found, that, during the generation of alcohol, all the fixed air which was given off was derived from the sugar; that the quantity of the sugar was equal to the sum of the alcohol and fixed air into which it was changed, and that the ratio of these bodies was 57 alcohol and 42 fixed air per cent.! The analysis of this philosopher also agrees with the structure here assigned to alcohol. He found that it consisted of water, and the olefiant particle; and the quantities deducible from his experiments are, 60.84 olefiant matter and 39.13 water, the true ratio being 60 of the former and 40 of the latter.

Alcohol is a hot, pungent, light, volatile liquid, existing in vapour, *in vacuo*, at a temperature of 13 cent., or 56° Fahr. and boiling in the air at 80 cent., or 170° Fahr. Its vapour is inflammable, and constitutes the combustible matter of the spirit-lamp. It has a great affinity for water, as might be inferred from its form. By itself, it may constitute laminæ, but the intervals between them are great, in consequence of the polarised repulsive fluid of so large a particle, and the great specific heat proper to a body possessing such poles. When decomposed by the abstraction of its water, olefiant gas is given out.

The most interesting property of alcohol is its power of inebriation. It is the basis of all sorts of ardent spirits; and these, when drunk in considerable quantities, produce a frantic intoxication.

In alcohol, the properties of the aqueous and pinguious menstrua are united in such a manner that it mingles with water on the one hand, and oleaginous bodies on the other. It is therefore a powerful solvent, and is much used as a medium for dispersing bodies in water, which are insoluble in that menstruum. The magnitude of its particle is well shewn by the phenomena that ensue when diluted alcohol is contained in such a tissue as a bladder. The water works its way through the pores, the alcohol is detained, and, in this way, absolute alcohol may be produced. Could alcohol be exposed to a very high temperature, and prevented from relieving itself, by assuming the gaseous state, it would probably be decomposed, independently of combustion, into steam, carburetted hydrogen, and carbonic oxide.

According to the nomenclature commonly used in chemistry, sugar is, then, a carbonate of alcohol, a solid, white, crystalline body, generated from two invisible gases, in the same manner as sal ammoniac, volatile smelling salts, and others. Nay, there is a very close analogy between the structure of volatile smelling salts (sesquicarbonate of ammonia) and sugar; and, could we substitute four volumes of alcohol instead of four of ammonia, and cause them to unite with three of fixed air, the result would be a white precipitate of sugar. Malic acid, in like manner, may be regarded as a bicarbonate, supercarbonate, or salt of alcohol, with excess of acid.

Ether.—When we consider the lightness of the olefiant particle, whose weight is 12, we are prepared to find that the same aqueous structure which can easily sustain, on its alternate segments, a weight of 71, or three saccharine particles, should be able to sustain a particle of olefiant gas on each of its six segments, whose joint weight is only 72.

It is evident that, to develope such a form from alcohol, it is only necessary to abstract the water from every other particle of alcohol in a mass, by some body which has a very strong affinity for water. Thus, if 62 parts of oil of vitriol be mingled with 60 of alcohol, there would be a sufficient quantity for decomposing every other particle of alcohol, and reducing the oil of vitriol to the state of monohydrated particles, in which it crystallizes so easily; and if the other set of alcoholic particles could be preserved from the access of the acid, and receive all the olefiant particles set free by the destruction of the first, the liquid would consist of 86 parts of oil of vitriol, of the specific gravity of 1.78 and 96 parts of the doubly olefiated alcohol. As the one boils at a very high, and the other at a very low temperature, by distillation the volatile part may be collected in the receiver, and the vitriol left behind.

Similar to this, is the process resorted to for generating ether from alcohol, though the transference cannot be effected so perfectly as here imagined. The acid employed also receives some very interesting modifications from the incidence of carbon and hydrogen. Fig. 76 represents a particle of ether. Its atomic weight is 96 (72 olefiant gas + 24 water.) It possesses the same properties as alcohol, but in a more eminent degree. The pinguious now predominates over the aqueous form, and it is now no longer notably miscible with water. Ether is a very light, very volatile, and combustible liquid. It has a peculiar odour and pungency, and it produces intense cold by the rapidity of its evaporation. When burned in vital or common air, water and fixed air are the products; but, when very slowly consumed, carbonic oxide, and consequently acetic acid, are produced. Acetic acid is also developed when ether is exposed to the access of air and light. This meagre combustion is beautifully produced, by suspending a coil of platina-wire over an alcohol or ether lamp, which is to be blown out as soon as the wire is red hot. The heat generated by the slow combustion of the etherial vapour, is adequate to sustain the incandescence of the metallic spiral; and, if we suppose a particle of ether to be divided into two, each part, by being supplied by three particles of oxygen, degenerates immediately into two ternate hydro-molecules of acetic acid, which, when produced in this way, has obtained the name of Lampic Acid.

Every particle of ether requires, for complete combustion, 18 of oxygen, from which there result 6 of water and 12 of fixed air. If, then, we could ascertain the density of the etherial particles in the state of vapour, we should be able to say how many volumes of vital air would be required for its detonation or combustion. An atmosphere of ether, however, appears to possess a very irregular structure. In every particle there are three volumes of olefiant gas, and there seems reason to conclude that the particles of ether are disposed neither in the same manner as the common gases, such as vital air and hydrogen, nor at double distances, as in many others: For, when a little ether is added to a volume of a gas, the whole is expanded more or less, seemingly to the end that a symmetrical structure may be established between them. Dalton also found the specific gravity of ether to be 3.125; and Gay-Lussac 2.586.

If we suppose the volume of its particle to be represented by three, that of hydrogen being two, and ammonia, &c. four, then every volume will require, for complete combustion, 6.75 volumes of vital air, from which 4.48 volumes of fixed air will result. Were it as dense as vital air, nine volumes would be required, from which six of fixed air would result. And, were it only as dense as ammonia, muriatic acid, &c. four volumes and a half would be sufficient; and this would produce three of fixed air. Now, Cruickshank found that one volume of the vapour of ether required for combustion 6.8 volumes of vital air; and, from the products, he calculated that the ratio of its carbon and hydrogen is 5 to 1, which is the true proportion. The analysis of Dr Thomson, and the views generally received by chemists, state ether to be composed of 35 parts olefiant matter, and 11.25 water, or 72 and 23.14, while the ratio here advanced is 72 and 24. But nothing short of the genius of Gay-Lussac could have applied his admirable theory of volumes to these substances, with the ingenuity which he has done, though, it must be acknowledged, the views here advanced as to this substance are quite at variance with them.

Besides sulphuric ether, there are many other sorts deriving their character from that of the acid employed to develope the ethereal out of the alcoholic particle, and containing dissolved particles of acid, sometimes in a pure state, sometimes variously charged with carbon and hydrogen, giving rise to new substances, such as sulpho-vinic acid, and others.

Fixed Oil.—Starch and fixed oil are the two great products of the aqueous and carbonaceous tissue of vegetables, and which serve for the food of the embryo, before the apparatus of assimilation is developed. It has already been presumed that a molecule of starch contains two senate molecules of water locked up in its centre. During the resolution of the starch into sugar, in the process of germination, it seems extremely probable that water, for the reception of the saccharine particles, almost crowded around the circumference of the amylaceous molecule, may be received from without; and the central senate molecules of water go immediately to the extension of the aqueous or cellular tissue in the germinating plant, operating, at the same time, as crystals to dispose to the development of more. Starch is most abundant in the vegetables of the ternate system, or those in which the aqueous tissue predominates; and, above all others, it is an abundant product of the gramineæ.

Fixed oil, on the other hand, is most abundant in plants of the quinate or carbonaceous system. Like starch, it possesses, very generally, the same characters, from whatever plant it is taken; and it seems to be connected with the vascular vegetable tissue, as starch is with the cellular. It is scarcely produced elsewhere than in the seed, from which it is extracted by crushing. Most nuts, hemp, flax, poppy, almond, rape, olive, and the seeds of many other plants, yield fixed oil abundantly; and, however different in natural characters the volatile oils obtained from the barks and leaves of different plants may be, the basis of the fixed oil of the cotyledons seems universally the same in its general characters.

Fixed oil, when pure, and the access of vital air prevented, is a very permanent body, and its individuality is so great that it unites into a soap, with alkalies, and may again be disengaged. It presents no traces of the ternate system, being abhorrent of all aqueous menstrua. The experiments on its decomposition have been so few, that many forms might be assumed to suit the condition of analysis. But several circumstances render it highly probable that the base of the fixed oils consists of carbon in the ligneous arrangement.

Now, if a portion of a spiral fibre, consisting of five particles of carbon, were to bend itself into a circular form, as it might do by the five internal angles uniting, or by conforming itself to a particle of carbon, or a pole of carbonic acid, carbonic oxide, or nitrogen, a quinate molecule of carbon would result,—the particles having the same relationship to each other as in the spiral vessel. Two such, joined by five of hydrogen, attached to the free angles, would form a symmetrical body, having a demand for two particles of carbon, or carbonic acid, to fill up its concave poles. From the decomposition of this body, carbon and hydrogen only would be procured, with that quantity of oxygen which might be involved in the carbonic oxide or acid. These, united various ways, by means of oxygen, would naturally give rise to various acids. But it seems probable that, in such an arrangement, the hydrogens are rather overcharged by the carbons, and perhaps vegetable fixed oil consists of three quinate ligneous molecules of carbon, such as have been described, united by ten particles of hydrogen, five on each side of the central quinate molecule of carbon. Such a form will be analogous to the first; and, like it, will be subject to the incidence of carbon, or its acid or oxide, on the concave poles.

Its symmetrical state is, when there are two particles of carbon only in the poles. Its atomic weight in this state is 105, composed of 85 carbon, and 20.10 hydrogen. If a particle of oxygen be applied to one pole, there is an addition of 8.7 per cent. of oxygen, and if a particle of carbonic acid be received on each pole, which is equivalent to both poles (of a body composed of 10 particles of hydrogen, and three quinate ligneous molecules of carbon), being constituted of carbonic oxide, 14.8 per cent. of oxygen is added, and the atomic weight is 135. Such a form would again be subject to the incidence of oxygen; and thus, besides carbon and hydrogen, oxygen would be obtained from the analysis, and if the hydrogens were attached to the poles of the carbons, and not to the angles of the circumference, they would give rise to nitrogen during decomposition; for as soon as the form is torn asunder, their poles being in each other's immediate vicinity, would very probably unite so as to constitute nitrogen.

In the form, when free from oxygen, the carbon and hydrogen are 81 and 19 per cent.; and if we admit a particle of oxygen on the pole, the proportions are almost exactly those assigned to Gay-Lussac as the constituents of olive oil *.

Whatever be the particular form of the particle of fat oils, there can be little doubt but the quinate ligneous molecule of carbon is that implied in their construction. Their most important chemical features are their union with alkalies to form soaps, and their fixedness in the air. From these soaps with fixed alkalies, another argument in favour of the quinate ligneous molecule will be derived when we come to these bodies.

Volatile Oil.—When the vegetable juices have been exposed to the sunbeam and air in the leaves, they are parted into three classes of substances. Water exhales into the atmosphere, and leaves the plant. Nutritious matter descends in the region contiguous to that where new wood is forming, and an excrementitious matter, composed in a great measure of carbon and hydrogen, is deposited in the cells of the bark, leaves, and flowers. This compound varies in every vegetable species, but it is always a volatile substance, more or less of an oily nature, possessing an odour so much that of the plant in which it is secreted, as to induce the belief that it is to the escape of their volatile oils that plants owe their fragrance. These essential or volatile oils are commonly obtain-

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* In this analysis the hydrogen is assumed, as usual, about $\frac{1}{9}$th of the water produced, and as it is really $\frac{1}{6}$th, the quantity of hydrogen stated in the analysis must be increased in the ratio of 6 to 9.

	True ratio.	Gay-Lussac.
Carbon,	85 or 77.213	77.213
Oxygen,	10 „ 9.088	9.427 ?
Hydrogen,	20 „ 18.166	19.32

If we diminish the oxygen by the quantity that the hydrogen is increased, it would indicate one particle common to two, which would give rise to a symmetrical form.

ed by distillation. They are extremely numerous, but none is produced in greater quantity than turpentine, which is the volatile oil proper to the fir tribe.

The constituent particle of the volatile oils seems to be a ternate molecule of carbon, with one of hydrogen, in the concave, and occasionally perhaps another on the convex pole. The particle of hydrogen in the negative pole of the ternate molecule, is attached by four angles, and the compound particle resulting, must be very penetrating and permanent, and capable of grouping round carbonic acid, carbonic oxide, and the bases of fixed oils in many ways. The ratio of the carbon to the hydrogen in this body, is 15 to 2, and its atomic weight is 17: where there are two particles of hydrogen, the ratio is 15 to 4. If we suppose with M. Houton Labillardiere, that turpentine, purified so that all oxygen is removed, is equivalent to four volumes of olefiant gas, and two of the vapour of carbon, the ratio of carbon and hydrogen, according to the mode of calculation, on which such suppositions are founded, is 2 to 14.88.

Bicarburetted Hydrogen, (Faraday).—If two ternate molecules of carbon had only one particle of hydrogen common to them, a symmetrical body results, and two such joined together by a particle of hydrogen, (producing a particle analogous to that of sugar, malic acid, &c.), seem to constitute that substance which Mr Faraday extracted from the condensed products of compressed oil gas. At natural temperatures it is a very light liquid, and, at the freezing point, it forms dendritic crystals. Supposing its vapour of the usual density, every volume would require for combustion seven and a half of oxygen. From this, six of fixed air would result, and one volume and a half would be occupied as water, along with the three particles of hydrogen proper to every particle of the substance. In 100 inches, there is as much carbon as in 300 of olefiant gas, and half as much hydrogen. Supposing its exclusive action upon the radiant to be the same then, 100 inches ought to weigh about $(30 \times 31)—6.3 = 83.7$ grains. Now, Mr Faraday calculated, that, at a mean temperature and pressure, its specific gravity was 40, that of hydrogen being 1, which gives about 84.7 grains as the weight of 100 inches. But in such vapours as those resulting from hydrogen and carbon, from which the radiant matter is excluded in so remarkable a manner, an equal distance among the particles, as that obtaining among other gases, cannot be altogether depended on, and little ought to be built on such coincidences as this.

Naphtha.—The combustion of carbon in ternate molecules is not effected so easily or perfectly as when it enters upon the gaseous state along with hydrogen, in single particles. Carburetted hydrogen, olefiant and binolefiant gas, alcohol, and ether, in which the carbon is not united in ternate molecules, burn with a flame, more or less intense, according as the quantity of carbon is greater or less, and without smoke. Those constituted of the ternate molecule, on the other hand, such as volatile oils, Mr Faraday's carburet just noticed, camphors, resins, and bituminous bodies, yield smoke as well as flame, and a proportional quantity of soot. The product of unburned carbon probably consists of ternate molecules, carried up by oxygen or aqueous vapour. It arises chiefly from a want of heat in the region of combustion, sufficient to break up the ternate molecule. It is also highly probable that some particles of hydrogen may escape combustion in the concave centre of a ternate molecule, and if a particle of water should alight upon this, it is evident that a particle of ammonia would speedily make its appearance. This being again decomposed, would yield nitrogen and hydrogen; according to which view, the occurrence of nitrogen among the products of coaly bodies is not to be wondered at. But if the ternate carbon remained upon the pole of the water, three edges of which are engaged, then, as soon as a free particle of hydrogen was in the way, and not repelled in consequence of its temperature, it might complete the form by entering the other pole of the water. The three particles of hydrogen in the water unattached, and unsymmetrically related to the axis, might now change their positions, so that their poles would seek the centre of the mass, and thus there would remain a particle of sulphur, charged with three of hydrogen, and a ternate molecule of carbon on the pole of the sulphur.

The tendency to form smoke is exemplified in all the bituminous bodies of which naphtha seems to be the base. In its purest state, naphtha is a colourless liquid, having a very penetrating disagreeable odour, and a nauseous taste. It is highly volatile, and possesses an oily habit. It is a somewhat abundant product of nature, occurring on the surfaces of lakes and springs, in a liquid state. It is also found in many situations as a solid, in which states it is known according to the degree of its cohesion and colour, by the names of Petroleum, Mineral-tar, Maltha or Mineral-pitch, Asphaltum, Elastic Bitumen, Mineral-caoutchouc, Resinas-phaltum, and Coal-tar.

Naphtha is remarkable among natural products (not simple) for containing no oxygen: hence it is fit for confining potassium in the metallic state. It is a too abundant product of the distillation of coals during the preparation of gas, and its reduction to olefiant gas seems to be very difficult; the abundance in which it is produced in the rude operation of distilling coal, would lead us to infer that it possessed some simple structure, and the same idea is suggested from its being a product of the mineral strata, in this respect differing from most other hydro-carbonaceous bodies, which are the result of organization.

Until something appear to the contrary, we may suppose it to consist of two ternate molecules of carbon, united by three of hydrogen, with a particle of carburetted hydrogen on each pole. Its atomic weight is 50, (40^8 carbon + 10^5 hydrogen), and its carbon and hydrogen are in the ratio of 80 and 20 per cent. The central form consists of two ternate molecules of carbon, united by three of hydrogen. It is equivalent to three of olefiant gas. Into this state naphtha will always be apt to degenerate by the departure of carburetted hydrogen.

Cyanogen.—M. Gay-Lussac has made us acquainted with a very curious body, to which, from the blue colour it gives rise to in its most important state of combination, he has given the name of Cyanogen. Like the compounds of carbon and hydrogen, which have lately occupied our attention, it is a product of organization. It is chiefly met with in blood, and other nitrogenated organic bodies; but it is also developed in the aërated juices of certain plants, such as those of the family Laurineæ, and certain Rosaceæ, of which nitrogen forms no part. It is produced in nature, however, only in small quantities, and, for the purposes of experiment, is disengaged from a state of union with mercury.

Cyanogen is a compound of three particles of carbon, on a common axis, united by particles of hydrogen on all the equatorial angles (Fig. 77, in which there is a particle of hydrogen on the pole, constituting hydrocyanic acid). Its atomic weight is 35 (15^5 carbon 20^{10} hydrogen). Under a pressure of 3.5 atmospheres, it is a transparent liquid; and in ordinary circumstances it is an invisible gas of the usual density. The hydrogens are so completely engaged and fixed on all their poles, that their capacity for heat is not notably greater than in forms such as nitrogen; hence, in estimating the weight of the gas, we must be guided by its atomic weight compared with that of common air. But it is so deficient in an equator, that it seems to follow, that, in its most perfect state, every particle shall be charged with five atoms of radiant matter [*].

Its refractive power is, however, very considerable; for ascertaining its weight, therefore, experiments must be resorted

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[*] If so, then the weight of 100 inches would be thus made up:

Weight derived from atomic weight compared with that of air, ...	52.3
Five atoms, ...	7.5
	59.8
Two atoms excluded, ...	3.
Weight to be found by balance, . .	56.8 grains.

to. According to those of Gay-Lussac, 100 inches weigh upwards of 55 grains. It is one of those gases which, like vital air and intoxicating gas, would probably never give the same result, when prepared by different chemists.

Cyanogen has a very peculiar odour, and is combustible. The position of the hydrogens, however, is such as almost completely to secure them from combustion; for, when a particle of oxygen is in the act of withdrawing a particle of carbon from off the poles, the poles of the hydrogens must slide along the edges of the retiring carbon towards the apex of the carbon, which is receding, and thus meet and form a particle of azote. Suppose a molecule of vital air to be opened up by the temperature of combustion, so as to admit a particle of cyanogen between its two parts, the two particles of vital air thus opened embrace the poles of the cyanogen with the phenomena of combustion. A repulsion is immediately instituted. The cyanogen parts into two at the equator. The hydrogens slip together towards the apex, thus moving symmetrically, and still sustaining a symmetrical form. The central particle of carbon is then exposed to the action of the vital air. The two particles of oxygen on the poles turn upon it, disengaging the nitrogen; and there results a molecule of citrogen, composed of three of carbon and two of oxygen. This is combustible, and is ready for the incidence of another molecule of vital air; and thus there results a molecule, composed of three of carbon and four of oxygen; that is, a particle of pyragyne. Or, if we suppose the particle of carbon disengaged from the centre of the cyanogen to remain in its position for a moment, then pyragyne is again evolved by the simple displacement of the two particles of nitrogen by two of oxygen. Thus, for the complete combustion of every particle or volume of cyanogen, four particles, or two molecules or volumes of oxygen, are required; and the result is one molecule or volume of nitrogen, and one particle, that is, two volumes of pyragynic acid gas. If the combustion has been regular, there is no change in volume of the mixed gases. During the moment, however, in which the particles of nitrogen are separate, it is only to be expected that some nitrous particles should be generated, and of these, nitrous acid would produce a diminution of volume. Neither is it to be expected that all the hydrogen would become nitrogen: the disengagement of a few particles of hydrogen seems extremely probable; and it is to be remarked, that, in the deflagration of cyanogen, which is very violent, there is not the same uniformity of volumes produced as happens in other cases. Cyanogen is absorbed by a great many bodies. It is taken down in large quantities by alcohol, and water absorbs several times its volume. In these media, however, it undergoes decomposition, in consequence of its own affinity for hydrogen, and that of the oxygen that is developed by the decomposition of the water for carbon. To engage the carbon of one particle as pyragynic gas, four of water must be decomposed, and consequently four of hydrogen set free. One of these hydrogens is occupied by a particle of cyanogen not yet decomposed; and thus there remain from the formation of every particle of pyragynic acid two of nitrogen and three of hydrogen, which, when presented to each other in the nascent state, give rise to a particle of ammonia. Thus, any quantity of cyanogen and water is, by partial decomposition, resolved into equal numbers of particles of hydrocyanic acid, pyragynic acid, and ammonia, all which occupy equal volumes. If we suppose two volumes of cyanogen and four of steam to be decomposed, which are the quantities required, there is no change of volume, for the three resulting particles occupy a double space. It is this complete occupation of the elements, and the existence in every particle of cyanogen, of the number of particles of carbon requisite to form one of pyragynic gas, that determines the evolution of this gas in this instance, instead of common fixed air, which is probably far more generally developed in other cases of fermentation and deflagration.

Hydrocyanic Acid. Prussic Acid.—When we recollect the structure of the base of the acetic and citric acids, we will be prepared to anticipate that cyanogen should have an affinity for hydrogen, and form, along with a particle on its pole (Fig. 77.), an acid body. The atomic weight of this particle is 37, which is the same as that of citric acid; but, unlike the latter, hydrocyanic acid is an expanded form, possessed of very different properties. It is very volatile, and may be easily sustained in a state of vapour. When a volume is presented to a portion of potassium, capable of evolving as much hydrogen as is contained in the hydrocyanic gas, it contracts to half its bulk, and pure hydrogen remains. All the cyanogen has been absorbed by the metal, and forms with it a cyanide analogous to a phosphuret, sulphuret, oxide, or other compound, in which a negative form, or one having re-entrant parts, unites with a metal.

The hydrocyanic acid may also be torn asunder in the voltaic focus, the hydrogen betaking itself to the negative pole, while the cyanogen, like oxygen, nitrogen, sulphur, and phosphorus, which it resembles in possessing a number of faces fronting the axis, is found at the positive pole.

The most interesting property of hydrocyanic acid is its violent poisonous quality. It is said that a single drop, placed on the tongue of a dog, caused death in a few seconds; which, even pleasing the imagination with the belief that it was a very large drop, and a very small dog, indicates a destructive power of marvellous potency. Its vapour also, when diffused in the air, produces narcotic effects, which the chemist must guard against.

The action of poisons still remains unexplained. Hydrocyanic acid must be a body of very powerful electrical affections, and consequently a powerfully disorganizing form. It is also so similar to the forms in the blood, that this fluid must immediately recognize its energy. That substance to the development of which hydrocyanic acid would dispose, is hydrocyanic acid itself. Hence a little of the poison introduced may soon generate more; and if, indeed, chemists are able to detect hydrocyanic acid in the bodies of individuals who have been poisoned by it, it would diminish the difficulty of supposing that it could have escaped decomposition, if we assume that more than what was swallowed had been developed in the system. A little lactic acid soon fills a basin of good milk with its form. The action of rennets, if investigated, might lead to some discoveries respecting the action of some poisons.

Hydrocyanic acid dissolved in water, even when excluded from air, is very liable to spontaneous changes, and decomposition sometimes commences an hour after it has been prepared. This formidable substance is of very rare occurrence in nature. It is found in small quantities in the leaves and cotyledons of certain plants; and the distilled water from the leaves of the *Prunus lauro-cerasus*, owe their poisonous qualities to its presence. To be able to announce the nutritious, medicinal, or poisonous nature of plants from observing their organization, will be one of the highest attainments of science, and will belong to another age. It is not a little curious to observe, however, that the four-valved anther which possesses so remarkable a structure, is generally associated with very active medicinal or poisonous qualities. It is found in the Laurineæ and Berberideæ, the former of which yield camphor, oil of cassia, sassafras, and many other interesting substances; and the bark of the barberry (if we may receive the testimony of those who have suffered from the jaundice) is worthy of a place in the pharmacopœia. This plant is also said to exert a singular energy upon the surrounding vegetation. The present fashion in the practice of medicine, of disesteeming vegetable principles, and introducing quantities of mineral substances into the animal system, is certainly very much against the economy of nature.

Cyanic Acid.—Besides the hydrocyanic acid, cyanogen being arrested previous to decomposition (while the oxygen remains on one pole, the other being inserted into a base) may give rise to a form which is called Cyanic Acid. By the decomposition of three particles of water, it becomes pyragynic gas, and the three of hydrogen set free unite with the two particles of nitrogen to form ammonia. In this case, if the cyanate is pure, there is no hydrocyanic acid formed; but it is easy to see that, in certain modes of decomposition, acetic acid must be generated. It is very curious to observe with what admirable ingenuity modern chemists are able to detect the decompositions and changes which take place in such cases as this; but it is scarcely to be denied that in all great matters relating to the economy of nature, but little knowledge has been gained since the days of Boerhaave.

CHLORINE, DEPHLOGISTICATED MARINE ACID.

It has been already remarked, that the quinate molecule of carbon (Fig. 64.), in which five particles are united by an edge, possesses a stability scarcely inferior to the single particle of carbon itself. It may, in fact, be regarded as composed of a particle of carbon in the centre, whose faces are covered by atoms of matter, from which results a symmetrical form, having five re-entrant equatorial edges, that are conformable to hydrogen; and when these re-entrant regions are covered by five particles of hydrogen, the form of the quinate molecule of carbon (Fig. 64.) is developed. It may be readily generated, then, in two ways. It has been shewn in a former page, that such a form, in whatever way developed, may be expected in the ocean. The ternate molecule does not possess sufficient compactness to resist the pressure and violent attrition to which it must be exposed in an unconformable element; and except when, by the aid of hydrogen, it can escape to the surface as naphtha, it would probably be speedily destroyed, all the carbon being ultimately arranged in quinate molecules. This body, however, is, in a remarkable manner, conformable to nitrogen, and the form which results is possessed of a very admirable symmetry. Such, indeed, is the form of a binate molecule of nitrogen (Fig. 14), that it is a mould for a quinate molecule of carbon. Its five equatorial cavities are conformable each to the reception of a particle of carbon: so that, if the expanded molecule of nitrogen should first be developed in a region where free particles of carbon exist, the incidence of five in the equatorial region of the nitrogen may be expected; or if the quinate molecule of carbon be first formed where two particles of nitrogen are present, the same form may be speedily evolved. This body (Fig. 15.) is Chlorine, a form of such symmetry and electrical power that it has not yet been decomposed. Its atomic weight is 45 ($25^{\dot{5}}$ carbon + $20^{\dot{2}}$ nitrogen). It does not occur in nature uncombined, but usually with a substance so nearly related to itself in the circumstances of its development, that it is a quinate molecule of carbon stopt while it consists of a particle of carbon with an atom of matter on every face (Fig. 7.), in which state it wants five particles of hydrogen to become similar in form to a quinate molecule. In this state of union, chlorine constitutes vast beds of a soluble saline substance, named Sal-gem, or Rock-Salt, which, when dissolved in water, decomposes a particle, which introduces one of oxygen and one of hydrogen into the form. Chlorine, along with hydrogen, for which, like the analogous forms, carbonic oxide, citrogen, cyanogen, it has a strong affinity, is also developed during the combustion of animal substances; and entering, at the same time, into union with the volatile alkali, constitutes sal ammoniac. It appears, also, that chlorine is produced at Abo in Finland, during the production of nitric acid from crude nitre, and is obtained in union with carbon, which, with nitrogen, must abound in the impure materials.

It does not appear that chlorine can be resolved into smaller particles in the laboratory. It appears, however, that, in certain compounds, one of the particles of nitrogen on the pole reverses its position, to obtain a form more suitable to the existing state of union. In this case, however, the carbon still retains the reversed pole of the nitrogen by six angles; and were it not for a want of symmetry with the other pole, and that it is more natural when a single convex angle constitutes a pole, this form might be retained for some time. When chlorine is disengaged from the state of union, however, in which this reversion seems to take place, the particles resume their legitimate position with explosive violence. If two could be presented to each other, each of which had one of its nitrogens reversed, they would unite, and constitute a binate molecule of a very symmetrical character.

Such a form, however, would immediately take ten atoms of matter to fill up the cavities between the quinate molecules of carbon and the solid icosaedron of nitrogen in the centre; and a body would result of great symmetry and strength, which could not be regarded as a binate molecule of chlorine, but would be very nearly related to it. This seems to be bromine.

Though chlorine does not occur in the free state in nature, it may be easily disengaged for the purposes of the arts and experiment. It is found to be a heavy gaseous body, of a yellowish-green colour, a very nauseous odour, and disorganising action upon the lungs. It is a form of great electrical activity, producing the phenomena of combustion, when metals, phosphorus, sulphur, and other bodies, are exposed to it. Carbonaceous flames, however, are not so bright in chlorine as in vital air. In the gaseous state, chlorine is subject, like cyanogen, to the attachment of five radiant atoms as the hollows of its equator; and hence, since its exclusive power, as indicated by its refraction, and its specific heat, are much the same as common air, the weight of 100 inches will be that of its constituents,—

Carbon, - - - -	7.75 × 5 = 38.75
Nitrogen, - - - - - -	30.
Atoms, - - - - - -	7.5
	76.25 grains,

which is the weight usually found by the balance. When suddenly compressed, chlorine becomes luminous, like vital air and cyanogen, and, under a pressure of four atmospheres, it exists as a bright yellow liquid, which does not congeal at zero. Like the analogous gases, it is largely absorbed by water, and its most symmetrical hydro-molecule must require five particles of water to each pole. Mr Faraday found that vapour and chlorine unite in these proportions, and a hydrate of chlorine results, which shoots into dendritic crystals at temperatures under the freezing point. The atomic weight of this molecule is 165. Chlorine is evidently fitted in a very eminent degree for discharging colour. From its known demand for hydrogen, it causes a particle of water near its pole to assume the shape of a particle of hydrogen, (attached to the pole of the chlorine) surmounted by a particle of oxygen. This is the same arrangement as in the deutoxide of hydrogen, which, having a demand for an atom of radiant matter, when it cannot get it otherwise, will destroy chromatic axes to procure it.

The solution of chlorine is found to be so valuable for discharging colours, that it is now commonly substituted in bleaching, instead of a long continued exposure to the sunbeam, which probably illuminates the extreme atoms of the chromatic axes so strongly, that they are successively repelled, and, mingling in the sunbeam, leave the body colourless.

Chlorine is also possessed of very valuable anticontagious powers. It would be a valuable accession to science, could physiologists make us acquainted with those morbific influences which are generated in certain diseases, and are capable of being insulated so far, that they may remain in the atmosphere of apartments, and attached to furniture. The extremes of nervous action and lethargy, which are exhibited in fevers, indicate that the radiant tissue of the system is in a morbid state; and, until something appear to the contrary, we may suppose that this morbid state induces a similar condition on certain rays of the external radiant matter to a certain distance around the patient, which, in consequence of its peculiar state of excitement, is no longer fit for being recognised by the pure light, and for being received into its rays; and thus, in infected chambers, there will be a number of radiant atoms charged with subtile matter of such a nature as is developed in the disease which originated them. These particles forming no part of the radiant medium, or being intruders into it, will be readily absorbed by many bodies, but more especially by such as chlorine, every particle of which might accommodate five. If we suppose that the chlorine, immediately on its disengagement, attracted five atoms to it, which might chance to be pure as well as infected, it is still in accordance with the views of affinity advanced in this work to suppose that, in consequence of the radiant medium's demand for pure radiant matter, and disregard for infected, the fully charged particle of chlorine, as it floats along, shall successively part with its pure atoms to the radiant medium, and absorb those that are infected. These views would lead us to believe, that, in certain states of fever (where delirium by such practice could be prevented), exposure to the sunbeam might be of use. But, doubtless, these views are very apocryphal.

Spirit of Salt. The Marine or *Muriatic Acid.*—Chlorine has a very strong affinity for hydrogen, constituting, along with one particle on one pole, a hydracid of much interest and great strength. The solution of chlorine in water, if exposed to light, is apt to degenerate into this acid; and it may be directly produced by mixing the two gases in equal volumes. While they are kept in the dark, each aërial tissue is able to sustain its own symmetry, and union does not take place; but the application of flame, or the sunbeam, causes them to unite with explosion. There is no contraction of volume, but the new gas (Fig. 17) is colourless, very acidous in its properties, and more impatient than chlorine of the gaseous state. When water is admitted to it, it is instantly absorbed; and when it is permitted to escape into the air, white fumes are perceived, from the incidence of the aqueous vapour on the hydrogerent pole.

There are three hydrated molecules which can be conceived. That containing the least quantity of water has one particle on the hydrogerent pole, and five round the edges of the opposite pole, or six altogether. The other, which is fully charged, has five particles of water on the edges of each pole, five on the edges of the equator of the chlorine, and one on the hydrogerent pole, or sixteen in all. Now, it appears from the tables of liquid muriatic acid, and is more expressly stated by Dr Thomson (First Princ. vol. i. p. 87), that the strongest acid consists of one particle of acid, and six of water; while that whose boiling point is a maximum, that in which the disposition, both of the acid and water, for the aëriform state is most completely counteracted, consists of one particle of acid united to sixteen of water.

Water is able to absorb above four hundred times its volume. The solution, when strong, emits suffocating fumes, and, in its most concentrated state, boils at a little above blood-heat. When the liquid mass consists of fully hydrated particles, however, its boiling point is higher than that of water. In all cases it is congealed with extreme difficulty. The solution in pure spirit of salt is colourless, intensely sour, and changes vegetable blues to red. It is a powerful acid, uniting with bases, and constituting saline solutions, during the transition of which to the solid state, very interesting phenomena occur.

In the voltaic focus the acid is decomposed, the chlorine going over to the positive pole, and the hydrogen, as usual, to the negative. No voltaic energy has yet been adequate to draw off the nitrogen from the base, nor indeed need we wonder at this; for, to judge from their forms, one would be apt to infer that the electrical state of a quinate molecule of carbon and nitrogen would be much the same, and, if so, the tendency of both towards the same pole would be equal, and decomposition could not be effected.

Sal Ammoniac.—Chlorine (Fig. 15), and Ammonia (Fig. 58) are quite unconformable to each other in every feature; while muriatic acid (Fig. 17) and ammonia are very highly conformable, and must evidently have an intense affinity. Hence, when chlorine and ammonical gas are mingled, there is a decomposition of the latter, accompanied with the emission of light, and a white powder precipitates, which is a muriate of ammonia. If all the hydrogen and chlorine have been engaged by the ammonia left undestroyed, there must only be a esiduum of nitrogen. Every particle of ammonia that is resolved, yields three of hydrogen, and can form three of muriatic acid with three of chlorine. These, with three of ammonia, fall as sal ammoniac, and there remains a binate molecule of nitrogen, which must evidently be equal in volume to half that of the ammonia destroyed; for one particle of ammonia has been destroyed, and it occupied a double volume compared with a binate molecule, or a particle of atmospherical nitrogen. The white precipitate of sal ammoniac equally takes place, when the acid and alkaline gases are mingled in equal volumes. When muriatic acid is exposed to aqueous vapour, a white precipitate in like manner appears, but it constitutes a liquid body.

When ammonia and muriatic acid are mingled in equal volumes, it follows that the particles resulting are composed of one of acid and one of alkali. But natural sal ammoniac seems to be constituted of large molecules, a hemisphere of one consisting of a hydrated particle of ammonia in the centre, with six of the muriate of ammonia around it, and a particle of water on each alternate segment of the mass. If such be its structure, its atomic weight is 572.

	Assumed ratio.	Berzelius' analysis.
Acid, . .	282	282
Ammonia,	182	179·5
Water, .	108	105·

Sal ammonia is a rather tough deliquescent salt, which is sometimes found crystallized in tessular forms. When a saturated solution is set aside to cool, very interesting phenomena take place during the progress of crystallization (Mohs' Mineralogy, vol. ii. p. 40). The taste of sal ammoniac is bitter and cool, and it may be deprived of its water by sublimation. It is found in volcanic districts, and is produced in small quantities in the sea. Ammonia, however, is not the ternate form which might be expected abundantly in the waters of the ocean, but another with isamorphous poles, afterwards to be noticed.

Chloric Acid.—Chlorine indicates its relationship to nitrogen very well in its habitudes with oxygen. In consequence of its highly negative state, its affinity is, indeed, weak, but it forms several well characterized compounds of much interest. None of them occur in nature; and for the purpose of experiment, they must be generated in a manner similar to the nitrous compounds. To develope the quinate acid, from which the others are to be derived, it is necessary, as in the case of nitric acid, to effect an union with potassa, which, in consequence of its own eminently quinate form, has greater power in inducing quinate arrangements than any other body. The nitric acid, in union with potassa, is developed in nature; but to obtain the chloric acid, it is necessary to pass chlorine gas through a solution of potassa. Part of the chlorine decomposes water, the oxygens crowning the hydrogerent poles of the chlorine group, in sets of five on the pole of a particle of chlorine which now goes directly in union with potassa. Besides the muriate, then, a chlorate of potassa is developed, which crystallizes in rhomboidal plates, having an adamantine lustre. The acid may be removed from the base with which it is united, upon which it exhibits the ordinary acid properties. It has no power of destroying colours, though, like other acid bodies, it reddens them.

The atomic weight of chloric acid is 95 (45 chlorine + 50 oxygen); and though it cannot be constituted by a direct union of the elements, it may, like the nitric acid, be regarded as a compound of one volume of chlorine with two volumes and a half of oxygen.

Perchloric Acid.—From the decomposition of chloric acid in different ways, various substances result, of which there is one containing a larger proportion of oxygen. It is named Perchloric Acid, and consists of a particle of chloric acid, with two additional particles of oxygen, one on each pole. It is not possessed of much interest.

Euchlorine.—The compound which has only one particle of oxygen on one pole, is an aëriform body bearing the name of Euchlorine, from its fine yellow-green colour. Its odour is like that of burned sugar. Water absorbs eight or ten times its volume, and acquires a lemon tint. Euchlorine approaches to an acid in its nature. It has the power of discharging colours, but it previously reddens them. It may be decomposed by detonation, in which case 50 volumes expand to about 60, of which 40 are chlorine, and 20 oxygen, the number of particles in both being equal. 100 inches weigh between 74 and 75 grains; hence it is one of those gases whose density is neither represented by two, or that of hydrogen or chlorine, nor by four, or that of muratic acid, but an intermediate number. It is very easily decomposed. The resolution is accompanied by a violent explosion, and the production of light, though there is a permanent expansion. This compound is procured by the action of muriatic acid, in certain quantities, upon chlorate of potassa.

Peroxide of Chlorine.—By the substitution of oil of vitriol, another heavy chlorous gas may be raised, which appears to consist of a particle of chlorine, with a molecule of oxygen on each pole. It possesses an aromatic odour, and has a colour still more richly green than euchlorine. At the boiling point of water it explodes, and a greater expansion follows, forty parts becoming sixty, of which only twenty are chlorine. Perhaps this body is, in reality, a binitrite of the base of chlorine, the particles of nitrogen being interposed between the particles of oxygen thus constituting nitrous acid. The dreadful explosions which occur in some of the compounds of chlorine, seem to be movements occasioned by the force of symmetry acquiring power to destroy some unsymmetrical state of union into which the mass has been forced by chemical affinity, in opposition to the laws of symmetry.

Of these exploding compounds, the most formidable is that which results when an atmosphere of chlorine acts on a solution of sal ammoniac. In these circumstances, there appear on the surface of the solution little globules of an oily habit, but of a nature so explosive, that they can scarcely be touched without fulminating. The result of their decomposition is four volumes of chlorine and one of nitrogen. But chlorine and nitrogen cannot be made to unite.

Sulphurane, (Davy).—By subliming chlorine through flowers of sulphur, they unite, and a liquid results which has a red colour by reflected, and a yellowish-green by transmitted light. It has an odour somewhat resembling sea-weed, and it emits acrid fumes which irritate the eyes. It is decomposed in water; and we are able to learn that it consists of a symmetrical form, in which a particle of chlorine carries one of sulphur on each pole. Or, it may be that a quaternate molecule of sulphur has one of chlorine on each pole, the chlorine occupying the place of the hydrogen in sulphuretted hydrogen. According to the former view, its atomic weight is 65 (45^1 chlorine + 20^2 sulphur); in the latter, it is 130, (90^2 chlorine + 40^4 sulphur.)

Phosphurane, (Davy).—By pursuing a method analogous to that adopted in the case of sulphur, and causing phosphorus to sublime through corrosive sublimate (a substance containing a large quantity of chlorine rather loosely engaged), a liquid is formed, which has an analogous structure to sulphurane. It is limpid, fumes, and is converted in the air and water into phosphorous acid and chlorine. Its atomic weight is 61 or 122.

Phosphurana, (Davy).—Phosphorus burns with avidity in chlorine gas, and a very interesting body results, which reddens litmus paper, and unites to ammonia, giving rise to a solid resembling an earth. It is a snow-white volatile solid, analogous in its structure to phosphoric acid, the oxygen being replaced by chlorine. Its atomic weight is 53 (45^1 chlorine + 8^1 phosphorus).

Chloride of *Selenium*.—Chlorine was united by Berzelius with selenium, and it must be confessed that the compound is noticed here, rather to show that the atomic weight of selenium advanced in this work, accords with its known combining weight, than from any interesting properties which the compound possesses. From the synthetic experiments of Berzelius, it appears that 1.782 parts of chlorine are united to 1.000 of selenium, which are in the ratio of 45 and 25.26, the true ratio being 45 and 26. The atomic weight of the chloride is 71.

Chloride of Tellurium.—Tellurium, introduced into chlorine gas, burns spontaneously, and a white semitransparent substance results, which readily rises in vapour, and settles in crystalline forms. Davy determined its composition to be chlorine 1.83, and tellurium 2.0. Now these numbers are to each other as 45, or one particle of chlorine, to 49.1, or two particles of tellurium very nearly, the exact number being 48. Its atomic weight is 93.

Chloric Ether.—We have already seen some indications of the carbonaceous nucleus of chlorine, in the vegetable odours of euchlorine, of the peroxide, and of sulphurane. In union with carbon, it gives rise to bodies of a mild aromatic nature, very similar in their aspect to the products of organization, though the quantity of carbon compared with chlorine, even in that which contains the most, is less than a half.

When chlorine and olefiant gas are presented to each other in equal volumes, they unite, and a colourless volatile liquid, of a peculiar sweetish taste and ethereal odour, is generated. It may be distilled without change. It evidently consists of a particle of chlorine, with one of olefiant gas upon each pole. The gases are mingled in equal volumes, and there is no residuum; hence, as the particles of olefiant gas are twice as dense as those of chlorine, they must unite with it in pairs. That such is its structure, is confirmed by the fact, that all those bodies, such as sulphurane and phosphurane, in which both poles of the central part are covered by particles of similar form, are liquids. Its atomic weight is 69, (45^1 chlorine + 24^2 olefiant gas).

Chlorides of Carbon.—Perchloride of Carbon, (Faraday).—By causing chlorine in unlimited quantity to act upon chloric ether in the sunbeam, Mr Faraday derived from it another substance, which condensed in dendritic crystalline spiculæ on the sides of the vessel. It consists of alternate particles of chlorine and carbon, and is, therefore, analogous to phosphorana. It has been named Perchloride of Carbon; but if the views here advanced be adopted, the discoverers of many chemical substances will not refuse to give them more expressive names.

When the chlorine is supplied in abundance, it thus distributes the olefiant gas very economically, the olefiant particles in every particle of chloric ether being able to engage five of chlorine, besides its own nucleus, two as muriatic acid and three as the perchloride of carbon, in which state the nucleus itself is left. This substance is a friable white solid, having the appearance of sugar when scratched. It has little taste, but its odour is like that of camphor. It is not readily combustible, nor easily destroyed by the action of the stronger acids. It is volatile, subliming like camphor towards the light. It may be fused, and made to boil. It is sparingly soluble in water, but readily in alcohol and ether, and its alcoholic solution, like that of camphor, is decomposed by water. Its atomic weight is 50, (45^1 chlorine + 5^1 carbon).

Protochloride of Carbon, (Faraday).—By subliming the former substance in a state of minute division, Mr Faraday succeeded in parting it into two, one of which was pure chlorine, and the other chlorine charged with a particle of carbon on each pole; it is therefore analogous to sulphurane and phosphurane, and, like these bodies, is a liquid. It retains an odour of camphor, and, like the other, has a very high refractive power. It unites readily with alcohol, ether, volatile and fixed oils, but not with water. Held in the flame of a spirit-lamp it burns with a bright yellow flame, giving off fumes of muriatic acid.

The Chloride of Carbon from Abo.—During the process of preparing nitric acid from crude nitre at Abo in Finland, very small quantities are formed of a substance found in soft adhesive fibres, of a white colour, and an odour somewhat resembling spermaceti. On the application of heat it fuses and boils. At a lower temperature it sublimes, condensing in the form of long needles. Chemists have not yet succeeded in forming it otherwise, but its analysis shews that it consists of a ternate molecule of carbon (Fig. 63) united to a particle of chlorine. Its atomic weight is therefore 60, (45^1 chlorine + 15^3 carbon). In these interesting substances the relation of the base of chlorine to the organic kingdom, is shewn in a very satisfactory manner.

Chloro-carbonic Acid.—By exposure to the sunbeam in equal volumes, chlorine and carbonic oxide unite. They contract to half their volume, and an acid gas is the product. Its structure is analogous to muriatic and phosphorana acid. Its atomic weight is 65, (45^1 chlorine, 20^1 carbonic oxide). Its elements are held united by a weak affinity.

MANGANESE.

Carbon, when existing in the mineral strata uncombined with oxygen as carbonic acid, constitutes great beds of plumbago and anthracite. But it is also very abundantly distributed in the mineral kingdom in septenate molecules, which may possess either of two arrangements. The poles of this form (Fig. 65) are, however, eminently conformable to oxygen; hence, in nature, the septenate molecule always occurs in union with oxygen. The oxygen with which the molecule is united, can be wholly expelled only with extreme difficulty, as by a continued application of the most intense heat that can be raised, and the presence of charcoal to carry it off as carbonic acid. In this way, and even by the application of fire without charcoal, the carbonaceous molecule has been obtained in a pure state. It is known by the name of Manganese. Its lustre is probably somewhat higher than that of coke. Both are equally metallic. Like charcoal it is extremely infusible, and has only been procured in a few small globules. The weight of manganese is about double that of the diamond, and both are brittle.

In this body there is an equatorial and polar region very perfectly developed; hence it is not in an inactive and quiescent state, like the duodenate molecule. It draws down the oxygen from the air, loses its lustre, and becomes an earthy friable body. Its affinity for oxygen is so great that it decomposes water with rapidity; the hydrogen disengaged carrying up some of the manganese, and acquiring the odour of assafœtida, which is a hydro-carbonaceous production of vegetation.

Peroxide, Black Oxide of Manganese.—The number of forms which may result from the union of manganese with oxygen may be very great. That which possesses the ratio most near saturation, at a natural temperature, appears to be when a particle of manganese has one of oxygen on each pole, (Fig. 78). The atomic weight of manganese being 35 ($35^{\dot{7}}$ carbon), that of this, the most natural form in which it occurs, is 55 ($35^{\dot{1}}$ manganese + $20^{\dot{2}}$ oxygen); and it is met with in nature very abundantly. It is usually associated with silex, alumina, iron, lime, and magnesia; but it appears, from the analysis of Professor Turner, that the Pyrosulite from Elgersburg consists of this oxide almost in a state of purity. As it usually occurs, it is not a crystalline but an earthy mineral, having a very carbonaceous aspect, and some varieties, like plumbago, have a greasy touch, and a dark streak. This oxide, which is commonly known by the name of Manganese, is very useful both in the laboratory of the chemist, and in the arts. It is found in such abundance all over the central parts of Europe and in England, that it is employed in the manufacture of glass, and in bleaching. When mingled in certain quantities with impure glass in a state of fusion, discoloured by combustible matter, it yields oxygen to the combustible, and the mass becomes limpid. If, again, it be mixed in a larger proportion, the whole acquires an amethystine tint, which seems to be that proper to this oxide. To its presence in fact the amethyst owes its colour.

Manganese is also used for disengaging chlorine from sea-salt, of which it constitutes more than a half. For this purpose diluted oil of vitriol is poured upon a mixture of salt and manganese, and heat applied. The vitriol demands the soda of the salt, and forms with it Glauber's salt. The muriatic acid set free might unite with the protoxide of manganese, and pure oxygen gas be evolved, were it not that the vitriol demands the protoxide also. Hence for every two particles of vitriol that are engaged (one with soda and another with protoxide of manganese), one of muriatic acid and one of oxygen are set free. The oxygen unites with the hydrogen of the muriatic acid, water is generated, and the chlorine escapes in the gaseous form.

Green Oxide.—If vitriol only be poured upon the manganese, and heat applied, pretty pure oxygen is given off; for the peroxide, when its electric energy is concentrated towards one pole, by its entering into union with acids, lets go the particle of oxygen on the other, and thus passes to the state of an oxide, containing one particle of oxygen to a particle of metal. This oxide may be obtained by precipitation from its states of union, by exposing any other oxide mixed with charcoal, to a white heat, or by transmitting a current of hydrogen gas over it, when it is hot. Its atomic weight is 45 (35^1 manganese, 10^1 oxygen). It possesses a green colour, and is either permanent in the air, or rapidly unites with oxygen, according to the state of separation of its parts. They may evidently unite among themselves into molecules, a convex pole of one occupying a concave pole of another; and thus, when they constitute axes among themselves, of considerable length, their affinity for oxygen must be very inconsiderable. If, again, they exist individually, an addition to the axis, which is very short, compared with the equatorial diameter, and a symmetrical form, may be speedily expected by the incidence of oxygen from the air, an effect which, in both cases, must speedily be effected, when the molecules are separated by heat, and both assimilated in their condition. In accordance with these views, we find that Forchhammer and Arfwerdson prepared this oxide of such a quality, that it took fire when heated, and, at an ordinary temperature, attracted oxygen from the air; while Professor Turner prepared one which had been in a molecular state, for it underwent no change for many days.

Brown Oxide.—If, instead of oil of vitriol, heat only had been applied to the black oxide, oxygen in like manner had been disengaged, and in such proportion, as to indicate that every other particle of oxide had given off one of oxygen. After thus laying bare a pole, conformable to the pole of a particle charged with two of oxygen, one particle of peroxide, and one of protoxide, unite into one molecule; which is no longer decomposed by the heat, and the whole mass becomes an oxide, composed of two particles of manganese, and three of oxygen. In submitting to this change, the solid body ought to lose $\frac{1}{11}$th part of its weight, for the weight of two particles of black oxide, is 110, and that of the resulting united oxide 100. But the weight of the vital air obtained, ought to amount to $\frac{1}{10}$th of the original manganese used in consequence of the accession of weight, which oxygen receives on entering the gaseous state. It is said that the weight of the oxygen obtained is rather more than $\frac{1}{10}$th, which may arise from the existence of some oxide containing a larger quantity of oxygen, or some irregularity in the experiment.

This oxide, whose weight is 100, occurs in nature in considerable abundance. It is met with in prismatic and acicular crystals of a steel-grey colour; it is also abundant in the earthy state. As in other cases, the masses often contain more or less chlorine, which differs from manganese in such a way that, by the introduction of ten atoms of matter between the terminal particles of carbon and the quinate molecule, which forms the nucleus, it becomes isamorphous with chlorine. These ten cavities are perfect models for ten atoms, and the occasional transition of manganese into chlorine could have been anticipated, though chlorine and marine acid had not been disengaged from the native manganese-ores and water during the process of purifying them. This oxide occurs in nature, both anhydrous, and as a regular hydrate. The analysis of manganite, by Professor Turner, gives 89.9 brown oxide of manganese, and 10.10 of water. The particle of the oxide weighs 100, which is to 89.9 as 12, the quantity of water proper to it as a hydrate is to 10.78, a number not much above Turner's, or 10.10.

Red Oxide.—When any of the oxides of manganese is exposed in the open air to a white heat, it changes from a black, olive, or brown colour to a red, and differs from any other oxide in the percentage of oxygen which it contains. We have already seen that the black oxide is, by the first degrees of heat, resolved into the brown or deutoxide. To drive off a particle of oxygen from this, and thereby to resolve every particle of deutoxide into two of the protoxide or green oxide, requires very urgent applications. We may therefore expect to find the constitution of the red oxide such that it contains a larger quantity of oxygen than the green. It has been shewn that, in the generation of the brown from the black oxide, by the agency of heat, one of every pair of contiguous particles loses a particle of oxygen; and the convex pole, thus laid bare, occupies the concave pole of the particle yet charged with oxygen on both poles; the two particles, in consequence of the difference as to oxidation, being placed towards each other in the relation of acid and alkali. Now, by urging the heat still farther than that which developes this deutoxide, there results a form composed of three particles of manganese and four of oxygen. It is a particle of red oxide. Its atomic weight is 145 (105^3 manganese + 40^4 oxygen), and its oxygen is 27.48 per cent. There is a molecular form, however, which gives 28 per cent., and is probably of more frequent occurrence in nature. It consists of five particles of brown oxide, arranged around one of manganese, according to the number of its edges. Its atomic weight is 535 (385^{11} manganese + 150^{15} oxygen). It might be inferred, from the analysis of Hausmannite by Dr Turner, that this mineral is a hydrate of this molecule. The oxygen is a little more in quantity than in the red oxide; and the water is in such quantity as to amount to 11.73 on one molecule. The red oxide of manganese, then, generated in the fire, is exactly analogous in its structure to pyragynic acid, developed in a similar way, and both are ultimately composed of carbon and oxygen.

Manganesic Acid.—These four oxides do not, however, exhaust the combinations of oxygen and manganese, which are not less numerous than those of carbon and oxygen. One may be conceived, in which five particles of manganese are arranged round one of oxygen. Its atomic weight would be 185, and its oxygen 5.7 on 100. Another has been produced by Dr John, by exposing metallic manganese to the slow decomposition of water. It consists of two particles of manganese, united by one of oxygen. Its atomic weight is 80, and its oxygen is 14.3 on 100 of base. Besides these, there must certainly be one composed of two of oxygen and three of manganese, whose atomic weight is 125, and its oxygen 19 to 100 of base. These oxides, however, cannot be possessed of very specific characters or much interest.

But there are also compounds, in which the oxygen has a quinate arrangement, one of which is possessed of great interest. It is named Manganesic Acid. Its structure is similar to that of chloric and nitric acids. Like them it is developed through the agency of potash. By mixing with a salt of potash a quantity of the black oxide of manganese, and exposing to heat, a green coloured mass is formed, which, on solution in water, gives rise to a suite of colours from green to red, passing through blue and purple. It has been named the Mineral Cameleon, and reminds us of those changes to which nitric acid submits during its decomposition. Here, however, a quinate acid is in the course of being developed; and when the oxide of manganese has precipitated, a manganesiate of potash is found in solution, which may be crystallized into small prisms of a purple colour. These crystals have a structure analogous to the anhydrous sulphates, as will be afterwards explained. It may be only stated here, that, in one pole of the potash, there is a particle of manganese charged with five of oxygen, and the salt resembles on that aspect nitre and chlorate of potash. Like these salts, it deflagrates in a remarkable manner. But its relation to the diamond is indicated by its adamantine lustre, and to the vegetable kingdom, by its possessing the flavour of walnuts. By distilling the manganesiate of potash with anhydrous sulphuric acid, M. Unverdorben has disengaged the manganesic acid as a red transparent gas. It will be afterwards shewn that there is a particle of manganese on each pole of the potash, and five particles of oxygen on one of them; hence the atomic weight of manganesic acid is 120 (70^2 manganese + 50^5 oxygen). The analysis of Unverdorben gives 58.74 manganese to 41.26 oxygen, the ratio here stated, being 58.74 to 41.9. There can be little doubt but the particle of manganese on the opposite pole of the potash to that which contains the acidous body will be subject to the incidence of a particle of oxygen. From this another acid will result, whose atomic weight is 130 (70^2 manganese + 60^6 oxygen), and this corresponds to the manganous acid of Forchhammer. There may again be a form analogous to the perchloric acid, in which there are seven particles of oxygen to two of manganese. The most notable compounds of manganese and oxygen, then, may be thus expressed :—

	Manganese.		Oxygen.	Weight.		Manganese.		Oxygen.
Manganous acid (Forchhammer),	2	+	6	130	=	100	:	80
Manganesic acid (Unverdorben),	2	+	5	120	=	100	:	66
Black oxide, - - -	1	+	2	55	=	100	:	57+
Brown oxide, - - -	2	+	3	100	=	100	:	43—
Red oxide, - - -	3	+	4	145	=	100	:	38+
Green oxide, - - -	1	+	1	45	=	100	:	29—
———————— - - -	4	+	3	175	=	100	:	21+
———————— - - -	3	+	2	125	=	100	:	19+
Suboxide (Dr John) - -	2	+	1	80	=	100	:	14+
—————————— - -	5	+	1	185	=	100	:	5.7+

Salts of Manganese.

THE oxides of manganese, like those of analogous bodies, unite with acids, and stony or saline substances are formed. Those which are best defined seem to be compounds of the simplest or green oxide, with an acid. Few only of them crystallize, and they are distinguished by a red colour. It is, indeed, very singular to observe that, in manipulating with solutions of manganese, the same colours are obtained by the affusion of an acid or an alkali, as if they were vegetable infusions.

Sulphate or *Vitriolate of Manganese.*—It has been already stated that vitriol attacks the green oxide of manganese. The result of their union is a violet-red salt, which crystallizes in very flat rhombic prisms. It is not poisonous, but may be even substituted for Glauber's salt as a purgative. It is stated to consist of one particle of oil of vitriol, charged with four of water (that is, one on the naked pole, and three in the intervals of the equator of the particle of water implied in the constitution of the acid), united to one of protoxide of manganese, and that, in a state of solution, they are united particle to particle there can be no doubt; but the nucleus of a crystallizing molecule is probably a particle of acid; so that the ratio of acid in the crystals may be somewhat greater than that of 50 to 45, as is generally stated; and this has been found by Forchhammer. It is evident that the water cannot be expelled without altering the nature of the salt, and giving rise to an anhydrous sulphate; and so different in their natural characters are the salts formed by oil of vitriol and anhydrous sulphuric acid, that it will be convenient to denominate the former Vitriolates.

Acetate of Manganese.—It is very interesting to observe, that manganese forms with acetic acid a beautiful permanent salt. When speaking of acetic acid, it was mentioned that it generally entered into union with bases in the hydro-ternate molecule. Such appears, from the atomic statement of Dr Thomson, to be the case in this instance, each of the three bare hydrogerent poles of the acid being surmounted by one of water.

Phosphate of Manganese.—The oxide of manganese occurs in nature united with phosphoric acid and oxide of iron, constituting a very rare mineral. An insoluble white powder may be produced in the laboratory by their union, which consists of a particle of phosphoric acid on each pole of the oxide, and some water.

Carbonate of Manganese also occurs in nature, as might be expected. The carbonates are perhaps scarcely less numerous than the oxides, and no two analyses seem to agree with each other. As it is merely a white powder, very easily subject to decomposition, and as it is assumed in this work that there are two acids, both of which pass under the name of Carbonic, we need scarcely wonder at the variety of results indicated by different analyses.

Manganese also occurs in nature united to sulphur, but the state of an oxide is most congenial. Its relations to chlorine and barytes are very interesting, but none are so curious as the phenomena of its coloration.

SODIUM AND SODA.

When treating of the origin of nitrogen in the depths of the ocean, it was shewn that a body might be expected there composed of a particle of carbon covered by atoms on all its faces (Fig. 7.). There are on its equatorial aspects five re-entrant edges, conformable to hydrogen, or the external parts of oxygen. By the incidence of five of hydrogen, it becomes isamorphous with a quinate molecule of carbon, out of which, in the mineral kingdom, arises manganese or chlorine. This central part, composed of a solid bipyramidal decaedron, with a triangular pyramid on each face, is a particle of Sodium. Its atomic weight is 15. Like other forms having external faces of a re-entrant character, and conformable to oxygen, it is parasitic, and does not occur in nature in a pure state. Nor was it known to chemists as such, until Sir H. Davy relieved it from its engagement with oxygen in the voltaic focus, and exhibited it, at the negative pole, as a body of a bright metallic lustre, like mercury. At temperatures under the boiling point it remains solid; but it is easy to see that only a small quantity can be contained in a given volume, and that it must be much lighter than the diamond. The only way in which it can arrange itself from a state of fusion, is in duodenate molecules, which contain a large cavity in their centre, and between which the intervals must be great. It is found to be a little lighter than water,—a circumstance that seemed very anomalous, when the usually great specific gravity of other bodies possessing metallic lustre was considered. Sodium is a very abundant production of nature. To its presence the sea owes its saltness; and it is met with in union with chlorine, forming immense beds in the mineral strata. It also enters as a constituent into many minerals, and is extracted, for the purposes of the arts, from the ashes of sea-weeds and plants which grow upon the sea-shore.

Soda seems capable of performing the functions of potash in their economy; and while they grow in a region which supplies it in abundance, the mineral, instead of the vegetable, alkali is found in their tissue. The impatience of sodium in the insulated state is so great, that it is with difficulty preserved in it; and either on exposing it to air or water, it unites with oxygen. Two particles place themselves on opposite faces of the equator, the poles of the oxygen remaining exposed in the centre (Fig. 79.).

The atomic weight of sodium being 15, that of this substance, which is dry soda, is 40 (30^2 sodium + 10^1 oxygen), as agreed on by chemists. In this state soda was never examined, till it had been reduced as a calx from the metallic state. Its affinity for water is so great, that caustic soda, as produced by other methods, is always a hydrate. The dry alkali is a grey substance, of a vitreous fracture, requiring a strong heat for its fusion. On the admission of water a violent action commences, the soda becomes white, more crystalline in its aspect, and more fusible and volatile. When reduced to this state, it attracts fixed air and moisture from the air, becomes damp, then dries again, and falls into powder.

Soda is a very caustic and corrosive substance, changing vegetable blues to green, and yellows to brown. It also unites with acids, and possesses all the characters of an alkali in an eminent degree. Though not in a caustic state, it is extensively used in the arts for aiding the fusion of sand in the formation of glass, and for uniting with fat oils in the formation of soap.

Sodic Salts.

Common Salt.—The most interesting compound of sodium is that which it forms with chlorine, and which has been much esteemed from the earliest ages as a valuable addition to food.

Sodium and chlorine gas unite with the development of fire, and the substance which results has all the properties of pure sea-salt. It is a form of singular symmetry, and there is none among the salts analogous to it. A particle of chlorine has one of sodium on each pole, attached by six angles (Fig. 80.).

The ratio of chlorine and sodium is 45^{i} chlorine and 80^{i} sodium. When introduced into water, however, there is every reason to believe that its form expands; that a particle of water is resolved into the usual form which chlorine demands, and which consists of a particle of hydrogen between one of chlorine and one of oxygen. On opposite sides of this particle of oxygen the sodium is now placed, so that in a state of solution sea-salt is a muriate of soda. When evaporated, it is again resolved into the chloride or chloruret of sodium. This salt crystallizes in a form which, in a general view, seems to be a cube. On observing its evolution under the microscope, however, it appears that the crystal, during the successive periods of its increment, is a hexaedral trigonal icositetraedron, with either saliant or re-entrant faces; and the return into this form is also beautifully shewn during its solution, as we are informed by Professor Mohs. These crystals decrepitate in the fire, and sublime unchanged. This sublimation is sometimes resorted to for glazing pottery. Salt is also sublimed in volcanic action.

Glauber's Salt.—When sodium and sulphur are heated together, they combine, producing fire by their union, and a substance is formed, which, when heated in the open air, again takes fire, and is converted into a sulphate of soda. A similar substance is produced by the action of oil of vitriol upon sea-salt, which readily crystallizes from its solution. Its molecule probably consists of two particles of a fully hydrated vitriolate, united by a particle of water, into whose poles the two naked poles of the sulphur are inserted. A fully hydrated particle of soda has two of water. A fully hydrated particle of vitriol, one pole of which is covered by a base, requires six particles of water for the equator, and one for the naked pole of the sulphur; so that, were the particles of salt separate, there would be ten particles of water to each." But it is presumed that, to produce a symmetrical opposition of parts, two particles of the salt are united by a common particle of water, and that, therefore, in its most perfect state, Glauber's salt consists of 80 sulphuric acid, 40 soda, and 114 (equivalent to 9½ particles) of water. That such is the structure of the molecule, may be almost asserted, from the agreement of Berzelius, Thomson, and Henry, as to the quantity of water present in fresh Glauber's salt. Berzelius and Henry state the water at 56 per cent, which is equivalent to 114.5, upon 90 of the salt. Thomson finds very nearly 113. This salt, on exposure to the atmosphere, effloresces, and becomes earthy in its aspect, in consequence of the departure of its water. An anhydrous sulphate may be prepared by evaporating the solution of Glauber's salt in a gentle heat. Glauber's salt occurs in nature, along with rock-salt and epsom-salt, in the waters of the ocean, and that of certain springs. It also sometimes effloresces upon the soil, and on certain rocks. It has a very bitter taste, but is not poisonous, and is used in large quantities as a cathartic.

Selenites of Soda.—The selenious acid, or selenic acid of older authors, unites with soda in two proportions. The one may be regarded as a particle of soda with one of selenious acid in each pole, the other as a quaternate molecule of selenious acid united to one of soda. They are interesting only as shewing how perfectly the analysis of Berzelius is expressive of the atomic weights. According to him, that containing the largest quantity of selenious acid consists of 72.5 selenious acid, and 40 soda, 72 being two particles of selenious acid.

Soda, Natron.—The mineral alkali, when it obtains the simple name of soda, in commerce, is always united with more or less carbonic acid. Part of the soda of commerce is obtained from natron, a saline efflorescence, produced in many regions of the world, and consisting of common salt, glauber salt, and carbonate of soda. The remainder is obtained by incinerating sea-weed and maritime plants, the latter constituting barilla, the former kelp. The barilla of commerce being developed in the fire, we should expect it to contain pyragynic acid, whose weight is 55; and, that such is the case, is perhaps rather countenanced by the fact, that the common carbonates of soda are in a high degree soluble, while the true carbonates, into which fixed air only enters, are mostly of a dry stony nature. Now, a particle of pyragynic acid is evidently deficient in its equatorial region. We may suppose, then, that two particles of soda, one on each side, attach themselves around it, and five particles of water on each pole, besides more around the equator. Or, if we rather suppose that the soda is united with fixed air, which is the legitimate carbonic acid, one particle in each pole, as is the case in limestone, and the true carbonates generally, then a smaller molecule will result. In this case, the quantity of acid is 30, in the former it is 27.5 to 40 of soda. Common soda forms fine crystals, highly soluble, and containing so much water that the application of heat speedily liquefies them. It renders vegetable blues green, and possesses an alkaline taste, as is the case with other soluble carbonates.

Trona.—A variety of soda is found in considerable quantities in Africa, which possesses so much of a stony nature, that it is said to be fit for constructing buildings. It cannot readily be made to crystallize, but analysis indicates that it is composed of three particles of fixed air, with a hydrated particle of soda. It is also prepared artificially for making soda water, as it effervesces, and disengages abundance of fixed air, when mingled with such an acid as the tartaric.

Bicarbonate of Soda.—Soda, by exposure to carbonic acid gas in excess, may be made to unite with four particles, or two molecules, from which the resultant form is symmetrical.

The quantity of carbonic acid, supposing every molecule perfect, is 60 to 40 of soda. By the application of heat, it degenerates first into the tricarbonate, or sesquicarbonate, and ultimately into a true carbonate.

Phosphate of Soda.—One of the most interesting salts of soda is the Sal mirabile perlatum of the older chemists, the Phosphate of Soda of the moderns. It is readily obtained in a variety of crystalline forms. It dissolves in water, and fuses by heat. It may be reduced by the blowpipe to a pearly polygonal head, carrying oxides and earths to the glacial state along with it. Its taste is not nauseous, and its action on the animal system is so mild, that it is used in large dozes as a cathartic.

There are several varieties. One is a very soluble salt, of interesting crystallographic characters, named by Dalton, Quadriphosphate of soda, and which consists of one molecule of glacial acid, and one particle of soda; but the most perfect and most common is that which consists of a fully hydrated molecule of glacial phosphoric acid, united to two hydrated particles of soda. It contains 80 of soda, and 90 of phosphoric acid. It has been shewn, that one quinate hydromolecule of phosphoric acid is fully hydrated by 20 particles of water, while the two of soda require four. In the phosphate of soda, then, if fully hydrated, there ought to be 24 particles, or 288 parts of water to 170 of dry salt, *i. e.* 62.9 per cent. of water. These numbers are very accurately assigned in the analyses of Berzelius and Mitscherlich. The water is stated by Berzelius to be 62 per cent; and Thomson says, that, in his experiments on this salt, he found the water rather more than 62 per cent., though probably less than 63, (Thomson's System, vol. ii. 456). By forming the crystals in an uniform temperature of about 90, the ten particles of water on the polar particles of acid are omitted, and every molecule contains 14. By exposing either salt to heat or a sand-bath, all the water is drawn off, except that which is essential to the constitution of the molecule of glacial phosphoric acid.

On exposing the salt to a red heat, as has been shewn by Mr Clarke, the remaining particle of water is expelled; the whole structure is consequently destroyed, and there is a new substance formed, which consists of the acid and alkaline elements, in their most symmetrical position. This is perhaps when two particles of a symmetrical phosphate of soda are arranged with one of phosphoric acid for a nucleus. The new salt thus generated is less soluble in water than the other, and, in going into the crystalline state, takes only five particles of water; four, as usual, for the two particles of soda, and one for the naked pole of the central particle of phosphoric acid. In this salt there are involved two particles of the phosphate of soda, whose structure is given by Thomson, in his First Principles, and which is analogous to most phosphates. It consists of two hydrated particles of phosphoric acid, one on each pole of a particle of soda, which seems only to have one particle of water, and to be sometimes without any. The proportion of its elements are therefore 36 acid, 40 soda, and 132 water.

Those assigned by Thomson being

Phosphoric acid, ...	36
Soda, ...	40
Water, ...	136

(*Thomson's First Prin.* p. 272.)

Borax. Tincal.—This interesting salt of soda has been known in Europe for many ages, and is very useful as a flux in the arts of soldering, and experiments with the blowpipe. It crystallizes when in the purified state, but always remains somewhat unctuous to the touch. When heated, it intumesces, and undergoes a change analogous to the phosphate of soda. The quinate hydro-molecule is destroyed, and there remains a particle of boracic acid in each pole of a particle of soda. Like other weak acids, the number of particles of soda with which boracic acid is united in different sorts and conditions of borax, is very great.

The natural borax analyzed by Klaproth, yielded 80 parts of soda, 204 of boracic acid, and 260 of water. Now 80, 215 and 264, are exactly 2 particles of soda, one of the quinate hydro-molecule, and 21 of water. When this salt is exposed to heat, the molecular acid is destroyed. Every fifth particle escapes with the water, and there remain the two particles of soda engaged with the four of acid, one in each pole. In this the ratio is 40 soda, to 84 acid. Now, the analysis of calcined borax by Arfwerdson, gives 40 soda, and 88.6 boracic acid; that of Bergmann and Gmelin being 40 and 80; so that the ratio presumed lies between them.

But the most highly crystalline variety, whose features are described in Mohs' Mineralogy, contained no less than 8 particles of soda to each of the molecular acid, with 38 or 39 particles of water. For, neglecting the reduction to the exact numbers, it is evident that the quantities stated by the formula $\ddot{N}a\,\dddot{B}^2 + 10\,A\,q$ per cent. are very nearly the numbers equivalent to these quantities. The former of the following numbers are the quantities per cent., the latter are the true atomic ratios.

Soda, .	319.7 .	320 = 8 particles soda.
Boracic acid,	220.6 .	215 = 5 . . boracic acid.
Water, .	459.7 .	456 = 38 . . of water.
	1000.	981 atomic weight.

Arseniates of Soda.—Arsenic acid, in molecules, similar in form to those of glacial phosphoric and boracic acid, unites with soda, and gives rise to several salts and crystalline forms analogous to the phosphates and borates of soda. One of these, analyzed by an eminent chemist, who now regards the analysis as very incorrect, yielded 145 acid, 40 soda, and 241.1 water, the true ratio of acid and base being 140 and 40: there are besides several other arseniates, but they are not possessed of so much interest. If we include the particle of water essential to the structure of the arsenic acid, and which will generally go into fusion along with it, the atomic weight of the acid becomes 152, and the proportions of acid and base are 152 and 40.

Acetate of Soda.—One of the most common and permanent acetates is that of soda. It is prepared, in large quantities, from pyroligneous acid, and is much made use of in yielding a concentrated acetic acid. It was formerly known by the name of Crystallized Foliated Earth. It consists of a hydrated molecule of acetic acid in which the three naked hydrogerent poles are, as usual, crowned by water, with one of soda. It therefore consists of 66^{3} parts of acid, and 40^{1} soda, and 72^{3} water. The circumstance that crystals can only be obtained when there is an excess of soda in the solution, seems to hint that a particle of soda forms the nucleus of a crystallising molecule. If so, the molecule must be very large; for Berzelius' analysis almost exactly agrees with the structure of a single particle.

	Berzelius.	True ratio.
Acid, .	64.48 . .	66
Soda, .	40. . .	40
Water,	70.07 . .	72

Hard Soap.—By referring to the description, which was supposed to represent the base of the fat oils, it will be perceived how conformable it is to soda. The carbon in the centre of the former is conformable to the oxygen of the latter; and the carbons around it, both in the position of their edges, and in the inclinations of the planes of their equators to the axis, are also conformable. These oils pass into the state of acids, or perform the functions of acids, by uniting with the alkalies which possess forms analogous to that of soda, and the compound is that very valuable detergent, named Soap. Soaps formed with soda are generally of a hard consistence, and seem to be symmetrical forms, constituted by a particle of soda in the centre between two of the oily acids. On a particle of the best soap, however, there are probably 22 particles of water. Such an arrangement would be the reverse of that of starch, in which the water was protected in the centre by quinate forms, and solution thereby prevented. In the present case, the quinate pinguious form is in the centre, and the water around; so that it becomes, in the first instance, soluble in aqueous menstrua, and more intimately in pinguious menstrua. Soaps are incapable of crystallizing, agreeing in this respect with starch, and other merorganic bodies.

POTASSIUM AND POTASSA.

The name of potash has been already often mentioned in preceding pages. There is not a more interesting substance in the whole chemical series. The similarity of its nature to soda is so great, that it often requires the aid of chemical tests to distinguish them. It is, however, in every respect, a more powerful body, and the researches of chemists shew that its atomic weight is 60, and not 40. Potassium consists of ten atoms of matter arranged so that none of their faces are covered, (Fig. 7). It is isamorphous with sodium; but, instead of a particle of carbon for a nucleus, there is merely a cavity of this form. A body of such a structure is quite permanent. Its symmetry is very great; all the particles cohere by three angles, and no faces are opposed to each other, so as to occasion expansion. In the instance of phosphorus, we have already seen two atoms of matter sustained in union by their angles only; by-and-by we shall find that the most universally distributed substances in the mineral strata, are, like potassium, hollow.

Potassium was first obtained from the vegetable alkali by Sir H. Davy, and in its general appearance it very much resembles sodium. Its specific gravity, however, is, as we should infer, somewhat less. Were it wholly distributed in duodenate molecules, the intervals of which were equal to those of sodium, its specific gravity ought to be one-third less. Perhaps, were the specific gravity of potassium and sodium taken when both were in the fluid state, and at a temperature which was proportionally removed from the heat at which they become solid and aëriform respectively, it would be found that potassium weighs exactly two-thirds of sodium. A straggling unattached particle, however, diffused here and there through the mass, must render it far lighter than it ought otherwise to be. The specific gravity of sodium was stated at ·9348 by its immortal discoverer; and that of potassium, possessing a similar structure, ought to be ·623. Now, from his early experiments, Sir H. Davy deduced the specific gravity of potassium to be ·6. MM. Gay-Lussac and Thenard found it ·865, but it was pressed into a glass-tube. They also found sodium heavier than Davy's estimate, but not in the same proportion. When we consider, however, that the addition of ·0007 of its weight in hydrogen and ammonium, changes the specific gravity of mercury from 13·56 to less than 3, it will readily be granted that, in experiments on specific gravity, the utmost care must be exercised. That some such molecular arrangement is the cause of the uncommon lightness of these metals, appears from this, that, when they are reduced to the state of calces, in which this arrangement is destroyed, their specific gravity possesses nothing remarkable, but is similar to that of similar bodies formed of oxygen and common metals.

Potassium, at the temperature of freezing water, is hard and brittle, which indicates that it has assumed the crystalline arrangement more perfectly than sodium, for at the same temperature sodium is somewhat soft and malleable. Potassium enters upon this state about 50° Fahr., and melts at 136°, while sodium requires a temperature of 200° to effect the same. It assumes the aëriform state at a temperature a little below redness, while sodium requires a full red heat. This greater activity of potassium arises from its greater lightness and quantity of repulsive fluid, having a third part less matter, and ten faces more, than sodium.

Potassium has an affinity for oxygen still more intense than sodium. When a small bit is thrown upon water, it burns with a white and violet flame, and moves on the surface with great rapidity, disengaging hydrogen gas until it has completely disappeared. On examining the water, it is found to change vegetable blues to green, and to contain the pure vegetable alkali. On the equator of a particle of oxygen there are five edges, conformable to the parasitic edges of the equator of potassium; and though two on opposite sides formed the natural charge in the case of sodium, which is a less buoyant form, the natural charge of potassium is when all the five are covered, from which results a beautiful and powerful quinate form. (Fig. 81.)

Its atomic weight is 60 (50^5 potassium + 10^1 oxygen), and the metal and oxygen are in the ratio exactly fixed on from his experiments by the illustrious discoverer, since confirmed by the experiments of Berzelius, Gay-Lussac, and Thenard.

As might be expected, the oxygen is here fully charged; and it is remarked, that, when potassium burns in the open air, or vital air, it does not become potassa, but an orange-coloured substance, which gives out oxygen, and is resolved into potassa when mingled with water.

Sodium exhibits similar phenomena. It is probable that the number of oxides is very great; but so intense is the determination towards the natural alkali in both cases, that it does not appear in what way other oxides, in pure and homogeneous masses, could be generated, unless we possessed oxygen in a concrete form. There can be little doubt that the oxide of sodium, generated by heating sodium in plate-glass, or along with soda, is similar in form to potassa, as it is in appearance. But the oxides which occur in nature are possessed of most interest.

Potassa prepared without the access of water, is a grey body, with a vitreous fracture; but as it is prepared for the purposes of chemistry, it is a white brittle solid, of such acrid and corrosive properties, that it destroys the living fibre, when applied to it, almost instantaneously. One particle of potassa possesses no fewer than 200 facets.

As the affinity of potassium for oxygen is more powerful than that of sodium, it may be used to relieve the latter from its state of union. But it is evident that 50 parts of potassium will be required to disengage 30 of sodium, for these are the quantities that severally surround one particle of oxygen. Now, Sir H. Davy found that 50 parts of potassium were required to develope 29·49 of sodium, which is as nearly the ratio stated as could be expected. When the two metals are alloyed together, the compound, in most cases, remains fluid; at common temperatures they unite in all proportions; and the alloy, when solid, is brittle, even though but a little potassium be included. In most cases, however, it is fluid, as was found to be the case with the two isamorphous, but dissimilar bodies, sulphur and phosphorus, when mingled together.

The affinity of potassa for water is so strong, that it always exists in the laboratory as a hydrate, and no heat that does not decompose the potassa can set the water free. The water which it refuses to give up, is one particle for every one of potassa; and a symmetrical molecule of the hydrate would consist of a senate molecule of water, with six of potash around it,—a form somewhat resembling a flake of snow in the distribution of its parts, and which, were it capable of giving rise to crystalline forms, would develope a hexagonal plate. This is the structure of the true hydrates, but in a form so far from a state of natural equilibrium as caustic potash, perhaps it cannot be expected.

The great affinity of potassium for oxygen disables us from ascertaining whether it ever occurs in nature in the metallic state. But in some states of combination, and, no doubt, in the vegetable tissue in some period of its development in a free state, potassa is a most abundant production of nature. It enters into the constitution of all plants. It occurs in the waters of the ocean. It enters into the compositions of many crystalline minerals; and mica and felspar, two rocks of which a great part of the crust of the earth is composed, contain from 10 to 15 per cent. of potassa. The metal can only be preserved from the access of oxygen in naphtha, a liquid which, as has been shewn, neither contains oxygen nor matter in an arrangement that could be easily resolved into it.

Potassium and *Hydrogen.*—When potassium decomposes water, it appears that the volume of hydrogen disengaged is somewhat smaller than it ought to be, did every particle of water resolve itself into one of oxygen and one of hydrogen, and all the latter escape in the gaseous form. This is indeed more than could be expected, where it is nascent in such quantities and in such contiguity. But besides that the particles of hydrogen set free may, in some instances, unite and regenerate water, which is only the liquid state of hydrogen, the ascending gas carries up potassium along with it; nor is a particle of hydrogen more heavily laden by one of potassium than by two of carbon, in olefiant gas. There seem to be two compounds of potassium and hydrogen analogous to carburetted hydrogen and olefiant gas, the latter of which is inflammable in the air, and would probably generate by its combustion the pure peroxide of potassium. There is also a solid compound of potassium and hydrogen.

Potassic Salts.

Potassane, Chloride of Potassium.—In that interesting substance chlorine, potassium burns much more vividly than in oxygen gas, and a salt is obtained similar to the dry muriate in its properties. It has been long known under the names of Febrifuge Salt of Sylvius, and Regenerated Sea-salt.

It differs remarkably in its form from common salt; its crystalline structure is also dissimilar, nor is it ever applied to the same purposes. On the pole of chlorine there are five regions, as conformable and suitable for the reception of five of potassium as those around oxygen. Were potassium not so large a body, we should have two well-defined chlorides, in which there should be five on each pole of chlorine; and, perhaps, by mixing the chloride with potassium, such a body might be generated. The atomic weight of the chloride is 95 (45^{i} chlorine $50^{\dot{5}}$ potassium), as has been ascertained by analysis; that of Gay-Lussac differs from this constitution only by .09 of a deficiency in the chlorine.

When this salt is mingled with water, there can be little doubt but the particles of potassium abandon their position on the chlorine, and surround the oxygerent pole of a particle of resolved water, constituting a muriate of potash, as in the case of soda.

Nitre.—The highly quinate form of potash renders it eminently serviceable in developing quinate acids, and to its agency the chemist owes his possession of the nitric, chloric, manganesic, and tartaric acids. The generation of nitric acid in union with lime and potash, on surfaces contiguous to the atmosphere, has long excited the interest of chemists. Next to potash, as will be afterwards shewn, lime is the most highly quinate form among alkaline or earthy bodies; and therefore, next to the vegetable alkali, is most favourable for the incidence of nitric acid. When there is a concave pole, such as that of potash or lime, surrounded by five parts, having a demand for nitric acid, it is difficult to see how its generation could be prevented otherwise than by sustaining a very strong repulsion between oxygen and nitrogen, against the existence of which we have evidence. Both are naturally gaseous; and in the atmosphere, the oxygen is thinly distributed, compared with the nitrogen, and in binate molecules, out of which to educe the number five, would require the simultaneous formation of more than one particle of nitric acid. Besides, nitric acid, in a free state, is decomposed by the sunbeam. It is not to be wondered at, then, that it is not generated in the ordinary states of the air, which, as it exists, is in a state of electrical repose. As to the other nitrous bodies, I have presumed that they are compounds of oxygen and nitrogen in single particles, and if so, the atmosphere runs no hazard of being resolved into any of them.

But that nitric acid should be formed out of these elements by the incubation of such bodies as potash or lime, is only to be expected. The contiguous aërial particles being dissimilar, are not repelled from these bases, but are immediately incident upon them; and such is the state of the electrical equilibrium, that it may be said that one pole exists, to which nitric acid would be, as it were, a consecutive pole. Hence this consecutive form is developed, and the whole becomes quiescent. The presence of organic substances must, no doubt, facilitate this nitrification, both as affording nitrogen in the nascent state, and as congregating the oxygen of the air towards their carbonaceous elements. But a limestone rock, darkness, and damp are of themselves quite adequate to effect the same. The nitrate of lime, like most of the other nitrates, is so little in a state of electrical quiescence, that it attracts water from the air, and deliquesces. Of all the nitrates, nitre is eminent for its permanency; hence, when it is once developed, it is not again destroyed, nor is there any more perfect form into which it can be elevated, which can respond more perfectly to the symmetry of the potash. Lime, however, is a form which, as will be afterwards shown, possesses five ternate parts around the central oxygen, and of such a structure that each requires only four atoms to expand the whole into potash. Now, atoms must be abundant where there is liquid nitrate of lime; and where there is but a feeble light, they may be derived in any quantity from the radiant medium. Hence, as the lime had power to develope the nitric acid, so now, I presume, the nitric acid has power to repay it for its existence, by converting the particle of lime, to which it is attached, into the form of potash, and thus giving rise to a beautiful permanent efflorescence on the calcareous surface. The small quantity of nitrate of lime existing at any one period of the development, greatly aids this transmutation, for, if it were in quantity, the reaction of the mass would prevent the development of a new form. But, on the other hand, when the nitre once makes its appearance, it will increase rapidly, that which has been generated acting favourably for the development of more, as in other cases, of crystallization. Hence, it might be of much advantage to mingle a portion of nitre in nitre-beds, or to water them with a solution of it when they required to be moistened.

But there is yet another way in which nitric acid may be developed from air. Oxygen, when it receives a particle of hydrogen in its pole, becomes water. In the state of vital air, the access of the hydrogen is prevented by the atoms which occupy the poles; but when we consider the affinity of oxygen for hydrogen, it seems not improbable that vagabond particles, not prevented by the symmetry of neighbouring ones, or otherwise determined to maintain their position, may attach themselves to the outside of the oxygen by a facet, and thus wait there for a favourable opportunity of plunging into the centre, so as to produce water. Were there any such near a surface of lime or potash, five of them would immediately insert themselves into the concave poles of the base, and a particle of nitrogen from the atmosphere might complete the form.

The rapid transition of lime into potash would seem a very wonderful thing, were it not for their peculiar relations to each other, and to nitric acid. For, in other cases, the conversion of one undecompounded substance into another, is usually the work either of a very long time in the laboratory of the mineral kingdom, or it belongs to the secret works of assimilation in the organized. That such is the fact, however, there can be no dispute, for large quantities of nitre are gathered again and again from calcareous caves and walls, which are not known to contain any potash whatever. Nitre is an abundant product of several districts of the world, but still the natural supply is too small for the demands of the arts of life and death. It is therefore prepared artificially, by filling ditches with animal, vegetable, and calcareous substances, and protecting them from the sunbeam and showers.

It occurs in nature in crystalline spicula and efflorescing crusts, associated with carbonate, nitrate, sulphate, and muriate of lime. But it may be obtained from its solution in prisms, striated longitudinally, soluble, and very brittle. By the application of heat, the crystals fuse into a transparent penetrating liquor, which, when poured into moulds, constitutes Sal prunelle or mineral crystal.

When the heat is urged, nitre gives off nearly a third of its weight of oxygen gas. Along with a combustible, it deflagrates like other salts containing a quinate acid. When mixed with carbon and sulphur in such proportions that there is about as much oxygen as may convert the whole of the carbon into fixed air, it forms gunpowder, a substance so violently combustible, and generating so vast a quantity of elastic matter, that Count Rumford calculated that the initial force, during an explosion of gunpowder, is not less than 101,021 atmospheres. It seems not improbable that a part of the sulphur is resolved into hydrogen. If no water be present in nitre, its atomic weight is 130, composed of 70 acid and 60 potash; the determination of Dr Wollaston being 70 acid and 60·6 potash, and that of Homberg 66·8 acid and 60 potash. Analyses, however, give various proportions on both sides of the true number. Sir H. Davy also found water even in fused nitre.

Chlorate of Potash.—By passing a continuous current of chlorine through potash, a part of it is converted into a chlorate by the development of chloric acid through the induction of the potash. The salt, when procured in a free state, consists of plates having an adamantine lustre. It contains no water, and with combustible substances deflagrates more powerfully than nitre. Its constituents are the same, with the addition of a quinate molecule of carbon, which forms the nucleus, and may be concerned in imparting the adamantine lustre to the salt. This salt was long known by the name of Hyperoxymuriate of potash, a term which implies an erroneous view of its structure; and, if the views advanced in this work be sound, such is the character of the names of half the chemical substances which are founded upon the supposed structure of their particles, and not upon their remarkable properties according to the natural use of language; which properties, however, must be expressed in the nomenclature of their forms. This salt has been much used in the ultimate analyses of organic bodies, from the facility with which it yields oxygen to the hydrogen and carbon. It is not known to be developed in nature.

Tartar. Tartrates of Potassa.—It will be remembered that a quinate arrangement has been assigned to the oxygen in tartaric, as in the nitric and chloric acids, and that, like them, it is developed by the aid of potassa. The quantity of carbon present, however, renders it weaker, so that we have both a tartrate and a bitartrate, and its deflagrations are not so remarkable. The tartrate is an easily soluble salt, which seems to contain some water. If, indeed, we reflect upon the supposed structure of tartaric acid in the free state, we should readily believe that its salts should contain at least one particle of water for each of acid. The cream of tartar of the shops is a bitartrate, in which a particle of tartaric acid is found on each pole of the potash. From this there must result a form of singular elegance, though it is difficult to conjecture what may be the form of its crystallizing molecule. It may be noticed of all well-known substances, that there is something remarkable in the symmetry of their forms, compared with those which are confined to the manipulations of the chemist.

Manganate of Potash.—It is to the influence of potash, in like manner, that we owe the manganic quinate acid, which seems to be possessed of such interesting properties. The salt crystallizes in prisms, as is usually the case with the salts of the quinate acids, has a diamond lustre, a purple colour, a taste at first sweet, and similar to walnuts, but which leaves a very disagreeable impression in the mouth. When heated in contact with hydrogen gas, the crystals set it on fire, rivalling chlorate of potash itself in their power of supporting combustion. This salt, as is usually the case with the salts of potash, containing a carbonaceous acid, has a particle of manganese in each pole, and five particles of oxygen on one of them. These proportions, along with four particles of water, are very accurately assigned in the analysis of Unverdorben.

			True ratio.
Potash, ...	25·63 =	60 . . .	60
Manganesic acid, .	52·44 =	122 . . .	120
Water, ...	21·53 =	49 . . .	48

Sulphate of Potassa.—Potassa and sulphur have a strong affinity for each other, and constitute the Hepar Sulphuris of the older chemists. When exposed to the air this body becomes moist, of a green colour, and a fœtid odour, indicating the departure of sulphuretted hydrogen. The most quiescent form resulting from all sulphurets, hydrosulphurets, and hydroguretted sulphurets, is that which is developed, when, by the departure of sulphur, and union with oxygen, a form is constituted of one particle of sulphur in each pole of a particle of potash, and three particles of oxygen on the three external edges of the equator of one of the sulphurs. It is therefore merely an anhydrous sulphate, and thus oil of vitriol resolves itself, when it enters into combinations averse to the presence of water. There are other salts of potash with sulphur and oxygen, of which the sulphite or sulphureous salt of Stahl has been long known. It consists of a particle of potash with one of sulphureous acid in each pole. It crystallizes in rhomboidal plates, and, when exposed to the air with scarcely any change of appearance, it becomes sulphate of potash. Only one additional particle of oxygen is required for each particle of salt, and no change in the position of the sulphurs is necessary.

When oil of vitriol is supplied to potash in excess, a bivitriolate also is obtained, consisting of a particle of potash with one of oil of vitriol in each pole. But so averse is the quinate potash to the ternate water, when its demand for union is otherwise neutralized, that even the vitriol cannot take into the crystals more water than is essential to its own constitution.

The Carbonates of Potassa.—Potassa has a great affinity for quinate columnar forms, such as carbonic and oxalic acids, and unites with them in a variety of proportions. The most natural carbonate is that which is analogous to the true carbonates, and consists of a particle of fixed air in each pole of one of potash. This seems to be the vegetable alkali which occurs in nature, but it remains to be investigated whether the residuum of the crucible, when cream of tartar, or any more highly carbonated potash is heated, be this carbonate, or a particle of pyragynic acid, with one of potash on each side for an equator. The carbonated alkali which is the product of the incineration of land plants, is yielded in different quantities by different species, and it is more abundant in the leaves, and in herbaceous parts, than in those of a more woody character. Whether the potassium exist as potash in the living vegetable, has not yet been discovered. The potash obtained in this way crystallizes only with extreme difficulty, and is usually exhibited in concrete saline masses of a somewhat pearly lustre, and hence named Pearl-Ash. In this carbonated state, the alkaline properties of potassa are weaker than when it is a hydrate. It does not destroy the texture of cloth, but it instantly reacts upon colours as an alkali. It is readily soluble in water, and deliquesces in the air from the attraction of vapour. But it does not imbibe carbonic acid. As in the instance of soda, there are also two salts containing a larger proportion of carbonic acid. Of these, that named Bicarbonate, or which contains twice as much acid as pearl-ashes, is well known. It crystallizes readily, and if it be a true bicarbonate, or contain the same sort of carbonic acid as is most probably in the sesquicarbonate, the acid and base are in equal quantity, as appears almost exactly in analysis of Vauquelin. If, again, it contain pyragynic acid, 55 will be its weight to 60 of potash. Its demand for columnar forms, as indicated in its habitudes with oxalic acid, would, doubtless, render it very tenacious of pyragyne. But it were much to be wished that the whole series of carbonates were revised. The form of fixed air is so analogous to oxygen, and a particle of carbon so perfectly fills up the cavity between two particles of oxygen, that one is tempted to believe that, in such forms as pearl-ashes, or salt of tartar, the fixed air, when cemented by heat, might, in many instances, remain afterwards as a constituent of the base, and enter into union with an acid along with it. This might be especially suspected in such a form as potassa, which has a demand for more oxygen than that of its base.

If any such carbonated particles remained in a mass, the carbonic acid which would be indicated by the ordinary means of analysis would be too low. Again, since carbonate of soda is certainly an alkali, no reason can be assigned why sulphuric acid might not, in some cases, unite with it. It is easily conceivable, indeed, that the acid's affinity for the base may be much more intense, so that it displaces most of the fixed air. But it is not unreasonable to suppose, that a particle of potassa or soda, containing one or even two particles of fixed air cemented to its axis by heat, may constitute a base which even muriatic acid and heat could scarcely decompose. The poles of such a body are as conformable for union with acids as other alkaline and earthy bodies. Upon the whole, it seems most probable, that the carbonate, reduced from the bicarbonate by the expulsion of half its carbonic acid, contains one-third of its weight of fixed air, and that nine grains are required to yield six of potash.

As in soda, the greater the quantity of carbonic acid, the milder does it become in its taste and action upon the living body. The bicarbonate, like the same salt of soda, is often used as an antacid, and for forming effervescing draughts along with the mild vegetable acids, such as the tartaric and citric.

Oxalates of Potash.—Potash occurs in many plants united to oxalic acid, of which it may be regarded as the parent, in the same manner as it is the parent of the quinate acids. That which occurs is of course a binoxalate, or a symmetrical form, having a particle of oxalic acid in each pole; and here there is evidently an acid form, as in the natural carbonate there was an alkaline form. There is here a long axis, two convex poles, an equator, and seven particles of oxygen, involved in the constitution of the salt. Accordingly, it is found that this salt has the power of uniting with most alkalies and earths, and forming with them what have been called Triple Salts.

The origin of oxalic acid is easily traced. The binoxalate of potash is, in fact, only the carbonate, with two particles of citrogen added; so that it is a citrate of the natural carbonate, without the hydrogen, which is let go on account of the length of the axis: or it is the citrate, with two particles of carbonic acid added. There is also an oxalate, consisting of one particle of oxalic acid and one of soda; and if this salt contain one particle of water, and the other two, it is rather calculated to raise the suspicion, that oxalic acid united to potash is a hydracid.

By the ingenuity of chemists, oxalic acid has been made to unite with potash in two other proportions. The salts contain a considerable quantity of water, and as they possess eminently crystalline forms, they probably consist of large molecules.

Soft Soap.—Potash, like soda, unites with oleaginous matter, and forms a soap, which is in general of much softer consistence than the soaps of soda. It is hence not so convenient in use, and is more seldom manufactured. This greater softness probably arises from the greater perfection of its form, which has a greater tendency to the softness of organic tissues than the hardness of the crystalline. It may also arise from the presence of a smaller quantity of water, which aids very powerfully in producing hardness in bodies in which it is combined.

MAGNESIUM AND MAGNESIA.

A VERY white light powder, possessed of weakly alkaline properties, is found in the laboratory of the apothecaries, and it is known to be an earth which constitutes, almost alone, whole mountain ranges in certain regions of the earth, and, along with lime, many of the more recent strata. It bears to lime, very much the same relations that soda does to potassa.

It is a weaker alkali than lime, as soda is than potassa. Their neutralizing ratios are such, that if a certain quantity of acid demand 40 of soda to neutralize it, it will demand 60 of potassa; and if another quantity of acid demand 40 of magnesia, the same will require about 61 of lime. Like soda and potassa, magnesia and lime have both metallic bases; and the proportion of oxygen in magnesia and soda is greater than that in potassa and lime, nearly in the same ratio. Soda and magnesia are chiefly found in the inorganic kingdom, while potassa and lime are formed also by plants and animals. In a word, there are so many analogies, that we may expect to find between magnesia and lime a relationship of form similar to that which exists between soda and potassa.

The recent discoveries of chemistry have demonstrated that magnesia is a compound of oxygen with a metal; but the latter has hitherto been procured only in quantities so small that our knowledge of it is very imperfect. In fact, 50 parts of potassium are equivalent to only 16 of magnesium; and the form of the latter is also much less symmetrical; it is therefore much less patient of being insulated, and is so highly parasitic, that it unites with glass during its disengagement in glass vessels.

We found that a particle of sodium might be described as a particle of carbon, with all its faces covered by atoms; a particle of magnesium is one of hydrogen covered in a similar manner, (Fig. 6). Its atomic weight is consequently 8; and, as in sodium, there are only two, one on each side of a particle of oxygen, so in magnesia there are only two. (Fig. 82). The atomic weight of magnesia is therefore 26, of which 16 are magnesium and 10 oxygen. Berzelius states that he found magnesia to consist of from 38 to 39 of oxygen, and from 61 to 62 of metal, the mean of which is 38.5 to 61.5, the true ratio being 38.5 to 61.6!

Magnesia is a very light, white, tasteless, rather inert powder. It is infusible except in the extreme heat of the oxyhydrogen blowpipe. It is scarcely, in any degree, soluble in water, and its hydrate is decomposed at a red heat.

It has been met with in nature as a hydrate, containing one of water for every particle of earth. Its molecule is, therefore, a senate molecule of water, surrounded by six particles of magnesia; and its incipient forms of crystallization ought to be hexagonal tables like those of snow. Such crystalline forms have been discovered; but the hydrate is usually found in beautifully silky laminæ resembling talc. It is said that magnesia proves injurious to the vegetation of the soil in which it abounds; but opinions on such matters connected with agriculture are not always to be received without investigation. Magnesia unites with acids and forms salts, of which the chemist can enumerate the usual routine. There are only a few, however, that occur in nature, or are possessed of much interest.

Magnesic Salts and Minerals.

Carbonate of Magnesia.—Magnesia is found in some regions of the earth in abundance, united to carbonic acid. It does not, however, give rise to crystalline forms of great beauty like those of lime, nor is it at all regular in its habitudes with carbonic acid. Two particles of fixed air form the natural and quiescent charge for one of lime. There is every reason, therefore, to believe that they must be too much for magnesia, which is more easily saturated. In the native carbonate, there seems to be an excess of magnesia, and as it does not crystallize, perhaps its structure is no more symmetrical than that of the artificial carbonates, in which some of a group become true carbonates, some remain with only one particle, and some without any, according to the temperature and conditions of its formation.

Epsom Salt. Vitriolate of Magnesia.—One of the most interesting salts of magnesia is that which it forms with oil of vitriol. Like soda, it has no tendency to reduce the vitriol to the form of anhydrous sulphuric acid, but it readily unites with this acid. The salt crystallizes in prisms, permanent in the air, soluble, and of a bitter taste. Like vitriolate of soda, it is much used in medicine as a cathartic. The molecule seems to be similar to that of Glauber's salt or vitriolate of soda, and to consist of two hydrated particles united by a common particle of water, so as to produce a symmetrical form.

	True ratio.	Mitscherlich.	Thomson.
Acid, .	$100^{\dot{2}}$	100.8	100
Magnesia,	$52^{\dot{2}}$	52.	50
Water, .	$156^{\dot{1}3}$	160.4	157
Weight,	308.		

It is met with abundantly in the waters of the ocean and in those of certain mineral springs. It is valuable from affording magnesia, which is used as an antacid, by its decomposition.

Boracite.—Magnesia occurs in nature united to boracic acid, constituting a mineral which is always exhibited in a very highly crystalline form, and which possesses very interesting optical and electrical characters. It occurs along with gypsum and anhydrite. The analyses of Vauquelin and Westrumb indicate three particles of acid to one of magnesia almost exactly, and that of Pfaff nearly a particle of each.

Muriate of Magnesia.—This salt occurs in great quantities in the waters of the ocean, constituting about an eighth part of their saline contents. Like most true muriates with earthy bases, it is a very soluble and deliquescent salt. When resolved into a chloride, it is probable that little better than a mass destitute of individuality is the result. It might, however, be inferred that a symmetrical chloride might be formed, if chlorine and magnesium were made to unite in the ratio of five particles of metal to one of chlorine. The muriate consists of a particle of each of its constituents, and five of water: the true chloride of five of magnesium and one of chlorine;

hence, in the conversion of chloride into muriate, there must be a precipitate of magnesia, as found by Dr Thomson.

The remarks which have been made, when describing Magnesium and Magnesia, have prepared for the assertion that calcium is isamorphous with magnesium (Fig. 6.), but that, instead of containing two atoms in the centre, applied base to base, it is hollow. It possesses a highly metallic lustre; and, as we should expect, there is nothing remarkable about its specific gravity. Were it completely resolved into its proper molecules, which are ternate, calcium would indeed be a light metal, but still probably four or five times as heavy as water. Its atomic weight is 6; and five of them, as in the parallel case of potassa, invest one of oxygen to constitute lime. It burns with great splendour in the air, and quicklime is regenerated. In such an experiment, were the calcium all converted into lime, 100 parts ought to consume about 36.36 of vital air. The atomic weight of lime (Fig. 83) is 40, and its oxygen is one-fourth of the whole, or 25 per cent, Davy supposing there might be 27.2 per cent. There are many difficulties in the way, however, of discovering the true ratio experimentally. It seems not improbable that, where the quantity of matter yielding oxygen must be very great, compared with that of the metal, and more especially when the metallic particles are insulated from each other, some must escape in a form analogous to magnesia, with 2 particles of metal to 1 of oxygen, which, in small quantities, could not be distinguished from lime, being probably still liker it than magnesia.

The earthy substance produced by the reduction of calcium to a calx, is a very acrid powder, which changes vegetable blues to green, and has an intense affinity for water. It is recognised as the same substance, which may be procured by exposing limestone or marble to a strong heat for a considerable time.

Dry quicklime absorbs water with such eagerness that a hissing sound is produced, and there is a development of so much heat, that combustible bodies placed among it are burned. Hence ships, laden with quicklime, when they happen to spring a leak, are sometimes set on fire. The hydrate which results is a dry powder, possessing the usual structure. Though not perhaps when slaked in a rude way, yet, by chemical care, the hydrated particles may be made to group into their senate molecules, and the usual snow-like six-sided tabular crystals produced. Lime is, in a slight degree, soluble in water, and the liquid which contains it acquires a disagreeable taste, and the property of changing vegetable colours to their alkaline tints. When exposed to the air, lime-water becomes covered by a solid film, in consequence of the incidence of fixed air from the atmosphere, which forms with lime an insoluble stony matter.

Lime is a substance of great value in the arts of agriculture and architecture. Mingled with water, and a due proportion of sand, it forms the common cement of buildings, which, by the addition of certain metallic oxides, acquires the power of setting and remaining for a long time insoluble under water. In the soil, it tears undecomposed vegetable fibres into water and fixed air, for both of which it has a strong, though limited demand ; and, as these two substances are the chief pabula for plants, lime is a very valuable addition to most soils which are charged with undecomposed vegetable matter, or do not naturally contain a due supply of lime. When the living plant deprives it of its water or fixed air, for its own nourishment, the lime immediately derives more of both from the neighbouring earth or air, and thus keeps a supply of food and water between the plants and want. If it remained in a quick state in the soil, it would of course supply itself from the living plants, that is, it would kill them, and thus it might become food or poison, according as the condition of the soil and weather rendered it mild or exhibited it quick. So great, however, is its affinity for fixed air and water, that it cannot long exist in the soil in a pungent state. According to this view, the function of lime to plants is somewhat similar to that of vital air to animals. It becomes a cup for serving out fixed air and water to them, filling itself as fast as it is emptied by the vegetable.

Calcic Earths and Salts.

Chloride and *Muriate of Lime.*—Lime is used for condensing chlorine, and preserving it for the purposes of bleaching. Like other bodies, it absorbs the gas in large quantities; and, when hydrated, becomes capable of retaining a very full charge. The limit seems to be, when five molecules of chloride of lime surround a particle of lime, an arrangement which seems to obtain in the true muriate. In Dr Ure's experiments, the ratios are constantly found about this proportion; and that which he regards as the most accurate, gives it almost exactly. His ratio is, chlorine 39.40, and lime 42.22, the ratio of this molecule being 39.40 chlorine, and 42.05 lime. No crystalline forms, however, are developed; it continues to smell of chlorine; and, in water, it resolves itself, in the course of time, into muriate of lime.

Muriate of lime is found in the waters of certain lakes, especially those of the Dead Sea. It is extremely bitter, and so deliquescent that crystals can only be procured and preserved with difficulty. Its molecule seems to consist of a particle of lime, as a nucleus, around which are five muriated particles, with a large proportion of water. The analyses of this salt by Wengel, Marcet, and Berzelius, agree very well with each other. The ratio now assigned is 240 lime to 235 acid, or 50.77 to 49.7, the experimental numbers of Marcet being 50.77 to 49.9. When this crystalline mass is exposed to a heat equal to that sufficient to boil mercury, a transference begins to take place of the calcium from the oxygen to the chlorine. The hydrogen of the acid unites with the oxygen relieved, and escapes as water. The chloride which results, however, cannot be pure, if the salt has been forced to resolve itself from molecules such as those here presumed; it must contain a certain quantity of lime, amounting to about .042 of the crystals used. The chloride of calcium may also be generated by subliming chlorine through hot lime, when it is remarked that the volume of vital air developed, is equal to the half of that of chlorine detained. The chloride of calcium is, however, a forced body. The calciums are indeed conformable to the equator of the chlorine, but the poles, where they cannot be received, are the natural regions of attachment.

Carbonate of Lime, Limestone.—Lime possesses a strong affinity for fixed air, and forms along with it an insoluble earthy powder. In nature, the carbonate of lime occurs most abundantly, constituting, in the opinion of some geologists, about an eighth part of the crust of the earth, and comprising all sorts of marbles, limestones, calcareous spars, and tuffas. In primitive countries, the masses in which it occurs are generally crystalline, and in all æras crystals are found. Their forms are extremely various; but, when broken, they are all reduced to rhomboidal fragments, which, at the same temperature, have uniformly the same angles. Carbonate of lime also forms immense beds, of unknown extent, in the bottom of the ocean, which are the work of zoophytic animals. These corals even rise to the surface in many truly pelagic situations, and produce coral islands. The attrition of the waves gradually smooths their surface, and heaves up calcareous sand, washed from their acclivities, and sea-weed. The island becomes covered by vegetation, the seeds of the more perfect plants being wafted from other places by the ocean, or by birds; and ultimately there is a fertile island, covered with coloured mould, analogous to that which is found on islands of a different origin. The shells of the eggs of birds, oviparous quadrupeds, and of shell-fish, are also formed almost entirely of carbonate of lime; and it is to be remarked, that testiferous molluscous animals increase with greater rapidity when existing in a medium where calcareous matter abounds, than when in water destitute of lime; but the materials of coral islands, and the testaceous coverings of shell-fish, cannot be wholly derived from the waters of the ocean. Doubtless the lime is secreted by the animals; and, as far as we know, an animal to which a calcareous covering is proper, may provide itself with the matter which is necessary to its system, though there be no lime whatever in the surrounding medium; as an ox, a whale, an elephant, or a chick, in due season, is not found to be wanting in bone, though it neither eat bones, lime, nor phosphorus.

It appears that marbles, limestones, and calcareous spars, have very nearly the same chemical composition. Their structure is a type of the true carbonates, and consists of a molecule of carbonic acid, or two particles, one in each pole of the particle of lime. The ratio of lime to fixed air is 4 to 3, or 57.14 lime, and 42.86 fixed air in 100 parts. But the fixed air exposes two concave poles, which will be subject to the incidence of two atoms. This would cause the fixed air amount to 44.44 per cent. Or, if one of them remained with the lime, which would probably be the case if it were left in an unneutralized state, the fixed air lost would be 43.66 per cent.; and such is the range which the most accurate experiments perhaps cannot circumscribe. Now the quantity found by the best experimentalists is comprised within this range. The fixed air per cent. has been thus stated:—43.2 Thomson, 43.6 Berzelius, 43.7 Wollaston, 43.9 Marcet, 44 Thomson. There seems to be always a small quantity of water present, and often a very minute portion of magnesia. The atomic weight of carbonate of lime is 70 (40 lime + 30 carbonic acid). It is of great interest in physics, in consequence of its eminent crystallographic character and double refraction. Carbonate of lime in pure water is a very insoluble stone; but, when an excess of acid is added in the free state, it is dissolved in considerable quantities. The carbonate dissolved by excess of acid is very apt to part with it on coming to the open air and light; hence water, holding limestone dissolved by excess of its acid, lets it go where it forms a fountain; there it encrusts mosses and other bodies investing the fountain, giving rise to appearances similar to petrifactions. In the same way stalactites are formed on the roofs of dripping calcareous caves, and stalagmites on the floor, evaporation aiding in the deposition of the calcareous matter.

Sulphate of Lime. Gypsum. Anhydrite.—Lime occurs in nature abundantly united to sulphuric acid, constituting the well known mineral named Gypsum, or Plaster of Paris. Besides a particle of acid and one of lime, there are also two of water present to each particle of the mineral. It seems probable that lime has acquired that power which magnesia and soda (except in particular circumstances) do not possess, of parting oil of vitriol, and disposing of a particle of sulphur in each pole, while the three particles of oxygen are on the three equatorial edges of one of the sulphurs. In this mineral, however, as it usually occurs, there is a particle of water on each pole of the sulphurs. A variety is sometimes met with in which the water does not occur, and which is named Anhydrite; the transition from one state to the other is indeed easily effected.

By the application of heat the water is driven off from gypsum, and it then becomes a friable mass, which may be reduced to a very fine powder. On mixing this powder with water, the union is re-established; and, from the consistence of cream, the whole in a few minutes becomes a solid, at first of an unctuous, and by-and-by of a meagre touch. It retains a most minute impression of the mould in which it has become solid. Hence it is much used in the arts, for forming casts in architecture and statuary. Carbonate of lime is found in rocks of every age, but gypsum is chiefly confined to the more recent strata, occurring principally along with rock-salt and the new red sandstone. It is more soluble in water than the carbonate, and a lamina immersed in that liquid will soon indicate solution on the edges. It occurs in the granular state, and also highly crystalline. Its forms are quite different from those of calcareous spar, but its optical characters are scarcely less interesting. It readily cleaves into thin laminæ, capable of shewing the most vivid tints in singled light. The quantity of lime in 100 parts must, in this mineral, vary much more in analysis than in the case of carbonate; for (neglecting water) the quantity of matter attached to the acid part may vary from 50 atoms, which is the weight of naked sulphuric acid, to 56, in which the three concave centres of both sulphurs are occupied by atoms. The analysis of anhydrite, by Klaproth, gives to 40 of lime the sulphuric acid 52.6; gypsum, to Bucholz, yielded 54.2; while the analyses of Berzelius and Thomson give 55.2. It is probable, however, that gypsum is in reality composed of very large molecules, in which the number of particles of acid and base is not exactly equal.

Nitrate of Lime.—Next to potash, lime has a greater power to construct quinate acids than any other body. There is good reason to believe, that, during the transmission of chlorine through lime-water, some chloric acid is generated. Tartrate of lime occurs in nature; and the nitrate, as has been already mentioned, is the first form of nitre. It is not so permanent in the air as nitre, manifesting a great tendency to deliquesce. It agrees with muriate of lime in becoming luminous, when its water is driven off, and it is then known by the name of Baldwin's Phosphorus. When its constitution is perfect, the ratio of its acid and base is 70 to 40, which is the mean of the analyses of Dalton and Phillips.

Earth of Bones.—The earthy part of the bones of vertebrated animals is almost wholly composed of lime united to a phosphoric acid. The same substance is met with in the ashes of blood, and in all the fluids of the body. In the bones of the most perfect animals there is only a little fluate and carbonate of lime, but, as we descend, the quantity of carbonate increases, until, in the testaceous and crustaceous tribes, it occupies the place of the phosphate. Still lower in the scale, and on its confines with inanimate matter, the calcareous earth itself disappears, and is replaced by silica. The phosphoric acids are in the same predicament in reference to accessary atoms, as the sulphuric; and the phosphoric acid of a molecule of glacial phosphoric acid may weigh from 90, which is its naked weight, to 105, according as it is pure or fully charged with atoms; and, supposing that the earth of bones consisted of two particles of lime, and one of glacial phosphoric acid, the quantity of lime on 100 of acid, would vary from 88 to 76.2, according to the condition of the acid. Or, if we suppose it a phosphate, composed of two particles of phosphoric acid, one on each pole of a particle of lime, the quantity of base on 100 of acid will vary, according to the condition of the acid, from 111 to 95.2 parts.

It seems probable, however, that the real earth of bones is neither the one nor the other, but a compound of a certain phosphorous acid, consisting of a particle of water in the centre, with three of phosphoric acid on the alternate segments of the equator, and two of phosphorus on the poles, with a particle of lime on each pole. This is a very perfect and symmetrical form, and would agree well enough with analyses which are all different from each other. But, while this substance is somewhat beyond the reach of a satisfactory analysis, there seem to be a great many combinations of lime and phosphoric acid. Nor is their production in nature confined to animal bodies: a very interesting mineral which assumes highly perfect crystalline forms, occurs in nature, named Apatite, which is composed wholly of phosphoric acid and lime. To this mineral, also, different ratios of composition have been given by different analyses.

Borate of Lime. Datolite.—This mineral occurs crystallized, and also in compact masses, along with iron-ore and limestone, in primitive rocks, and also with fluor, quartz, prehnite, &c. Its analysis indicates very accurately that it contains the same relative quantities of lime and boracic acid as the highly crystalline borax, which has 8 particles of soda to 1 hydro-quinate molecule of acid; and to each such molecule of borate of lime, 4 particles of silex, and 2 of water, that is, a particle of hyalite, is added.

	True ratio.	Klaproth's Analysis.
Boracic acid, . .	$215^{\dot{5}}$	215.3
Lime, . . .	$320^{\dot{8}}$	320
Silica, . . .	$320^{\dot{4}}$	328.48
Water, . . .	$36^{\dot{3}}$	36
Weight, .	891	

Arseniate of Lime. Pharmacolite.—Lime occurs, though rarely, along with arsenical minerals, united to the arsenic acid. Its composition is somewhat differently stated; but there can be little doubt that it consists of one particle of the molecular acid, and two of lime, in a structure analogous to the phosphate. That from Andreasberg, analyzed by John, gave 140 acid, and 84 of lime; while the mean of all the three pharmacolites analyzed by Klaproth and John, and the picropharmacolite (which contains a particle of magnesia to every two of pharmacolite), analyzed by Stromeyer, gives 140 acid, and 75.2 of lime. The true ratio is about the mean of these. All the analyses indicate about 24 per cent. of water, which is equivalent to 6 particles. This mineral has much the appearance of white arsenic, but it is insoluble in water, and, before the blowpipe, melts into a white enamel.

Oxalate of Lime.—Lime occurs, somewhat abundantly, in the fronds of the crustaceous lichens, united to oxalic acid. The oxalate is also obtained in the laboratory by the affusion of oxalic acid upon a salt of lime; and as the oxalate formed in a neutral solution is perfectly insoluble, the oxalic acid becomes a valuable test of the presence of lime. In the powder, it appears that there are also two particles of water present.

The composition of oxalate of lime is stated by Dr Thomson.

			True ratio.
Oxalic acid, .	45	or 50	50
Lime, . .	35	39	40
Water, . .	22.5	25	24

SILICON AND SILEX.

When describing the structure of the radiant medium, it was shewn that eight atoms, circumscribing an octaedral cavity (of which four are represented in Fig. 22., though the atoms are much too close together), might be regarded as its molecule. Of all the forms of the universe, this, then, may be regarded as the most extensively diffused; and though, in the radiant medium the atoms are prevented from cohering, yet where atoms are sufficiently near each other, this form, composed of eight atoms, with an octaedral cavity, may be constantly expected. It is that which bears the most intimate relationship to the matter which occupies the celestial spaces, and this, as well as the ease with which atoms may group in this form, will induce to its evolution. It is very natural to assume that this body (Figs. 5. and the three along with Fig. 84.) must be silicon, which is, of all substances in the earth, by far the most universally diffused. In its state of quiescent union with oxygen, it wholly constitutes rock-crystal, quartz, and all sorts of flinty stones, and rocks. It therefore enters largely into the constitution of granite, gneiss, mica-slate, sand, sandstone, soil. In a word, silica is of universal diffusion, and is far more abundant in the crust of the earth than any other mineral whatever. Neither is it excluded from organized bodies. In plants it is met with in considerable abundance. There seems good reason for believing that culmiferous plants derive much of their strength from a network of silica interwoven with their tissue. In some, as the *Equisetum hiemale*, it is so abundant that they are used as files for polishing ivory. In others, again, as certain bamboos, little silicious concretions are found in certain regions, constituting the well-known substance Tabasheer, so remarkable for the small bending which it occasions to a ray of light entering its substance. There is something very peculiar in the form now ascribed to silicon. All the others that have yet been described, belong either to the ternate or the quinate system. Silicon, on the other hand, is obviously quaternate, and will not accommodate itself either to the one or the other. Now silica, in its habits with most reagents, suits our expectations in these matters, for none of the bodies hitherto described are capable of uniting with silica in any notable manner.

Silicon, the base of silica, has hitherto been procured only in small quantities, and, even when deprived of its oxygen, and consequently its electrical quiescence, it does not shew the same urgency to unite again, even with oxygen, that the other bases of alkalies and earths do. Even when in a diffuse mass, it does not decompose water at 212; and when, by the application of heat, its particles have been condensed into a symmetrical arrangement, its indifference to entering into union is still more remarkable. It is no longer combustible in common and vital air. Neither is it acted on by any acid (except the fluoric), and it combines reluctantly with the metals. It may be heated to redness along with nitre, without deflagration. It is not affected by solutions of the alkalies, neither does the flame of the blowpipe fuse it. To judge from its form, indeed, one would suppose it more infusible than carbon. It is combustible in the vapour of sulphur, potassium, and chlorine. A bit of silicon is a mass of a chesnut-brown colour, which has an earthy touch, and no metallic lustre. This very interesting substance has only lately been insulated, by the great skill of Berzelius, in sufficient quantities to ascertain its properties. In the accessible parts of the globe it seems generally to occur united to oxygen, and it is in this state of union only that the chemist obtains it in analysis.

Now, neither five nor two particles can be admitted around one of oxygen, so as to give rise to a form of such symmetry as in the other cases of the union of bases which have been noticed. Five are impossible, and two on opposite sides form a very straggling body, of so little symmetry, that if there were other three in the neighbourhood, consisting of one particle of silicon united to one of oxygen, they would certainly relieve the awkward state of the other, by all the four combining. This gives rise to a form of very admirable symmetry (Fig. 84.) and most peculiar characters. Its atomic weight is 80 (composed of 40^5 silicon + 40^4 oxygen). The oxygen and silicon are consequently in equal quantity. This agrees almost exactly with the ratio of Berzelius, which is 40 silicon and 40.4 oxygen. It has already been seen how little silicon, in consequence of its unsuitable form, is disposed for entering into union with other bodies. But from this it would not follow that silica should be equally averse, for it is usually on the concave poles of the oxygen that the descent is made by acid bodies, and had these been exposed, silica had been subject to solution by acids like other earthy bodies. It is to be noticed, however, that such is the only possible structure of a symmetrical molecule of silica, that while there are only five particles of silica, all the eight poles of the oxygen are completely protected from the access of any body whatever! So that silica, still more than silicon, is adapted for a permanent existence in the midst of solvent menstrua.

It requires two such molecules to constitute a form perfectly symmetrical, hence we may often expect to find silica existing along with other earths, in crystalline bodies, in double molecules; and as there are four regions of attachment, other bodies will be distributed around the single or double molecule of silica, so that their sum is four, and not either three or five, according to the numbers developed in other cases.

But while such are the characters of a perfected molecule of silica, we may also regard it in the nascent or imperfect state in which one particle of silicon is attached to one of oxygen. In this condition it possesses a great analogy to acid forms, and, like others which have a particle of oxygen exposed in a similar way, may be expected to be soluble in water. Into this condition also silica is probably resolved, at least in part, when it unites with the fixed alkalies, so as to form glass. Now, Berzelius found that nascent silica differed remarkably from the earth of flints in its properties.

It is so soluble in water that the solution, after only a slight evaporation, gelatinized.

Silica is usually obtained for the purposes of experiment, by destroying the crystalline structure and cohesion of a piece of quartz or rock-crystal, which is wholly composed of this earth. In what state of aggregation it is obtained is not known, but it is a meagre gritty earth, of a snow-white colour, insoluble in water, and even refusing to become plastic with it. Its affinity for water is not very great, for all its hydrates are decomposed by a red heat, and their number is very great. Its most interesting relations in chemistry and the arts are those which it bears to the fixed alkalies. A strong alkaline ley dissolves silica, and a compound results, named Liquor silicum, which ranges in solubility from that which melts in cold water to the most permanent glass, according to the quantity of silica present. Glass, then, is a compound of silica and a fixed alkali. It is probable that the individuality of both is destroyed, and that the silicon and sodium, if soda has been used, are grouped around the oxygens, so as to produce the arrangement most quiescent in the circumstances of combination. Glass has a conchoidal fracture, and exhibits no traces of crystallization. But, when suddenly cooled from the outside, a bit of glass remains permanently, of different densities; it acquires individuality of form, and, consequently, different repulsive states in different regions, and gives colours with singled light, similar to those afforded by truly crystalline bodies. When cooled very slowly, it becomes more tenacious and opaque, as if alumina had entered into its composition.

Hydrates of Silica.

Silica, in union with water, forms a great many hydrates, some of which are found in nature, and some are produced in the laboratory. But, unlike many other bodies, silica, in combination with water, is much more averse to crystallization than when dry, and reminds us of those merorganized masses which are met with on the confines of the organized and inorganic kingdoms, investing nuclei or filaments, whose organized structure is more unequivocal.

The beautiful crystalline forms of rhomboidal or common quartz, are either anhydrous, or contain a most minute quantity of accidental water. But the different substances which refuse to assume the crystalline form, and are grouped in the species named Uncleavable Quartz, are all regular hydrates.

Thus, common opal consists of three molecules of silica around one of water, according to the usual arrangement. An opal found in the graphite mine of Pfaffenreith proves, from the recent analysis of Schwitz, to be composed of silica symmetrically hydrated; that is, every particle being supplied by four of water, or perhaps with one of the four common to two contiguous particles of silica. Besides these, several other hydrates may be prepared in the laboratory: thus two hydrates may readily be procured by disengaging silica from soda or potash, with which it has been fused. When a small quantity of water is used, one is obtained, which is insoluble, and consists of one molecule of silica, and two particles of water. When a large quantity of water is used, a soluble mass, which, by evaporation, becomes gelatinous, is obtained. When a mass of this substance is left in a natural temperature for some weeks, it becomes a hydrate, analogous to the mineral found in the graphite mine of Pfaffenreith, and containing accurately four particles of water to one of silica. After exposure unbroken upon the filter for six weeks, Dr Thomson found silica 2, water 1.207; or silica 80, water 48.28, four particles being 48. The beautiful mineral, Hyalite, which is met with in the cavities of wacke and other analogous rocks, and is so limpid that it is almost invisible, is composed of a double molecule of silica, and a particle of water. Precious opal, so remarkable for its play of colours, consists of two double molecules of silica, and a ternate molecule of water. Menilite is a true hydrate, consisting of a particle of each, and such also seems to be the structure of semi-opal *.

Besides these, there are many other minerals constituted in a great measure of silica; but alumina, lime, oxide of iron, soda, and potash, also enter into their composition; and when the resulting form is symmetrical, there is every reason to believe that the distribution of these substances is symmetrical, and that the molecules are large. Most of the conspicuous minerals of the system, however, seem to possess a very simple structure, and some of them will be noticed when treating of alumina, which most generally enters into union with silica. From a few of them alumina seems to be almost wholly excluded. Thus Okenite, a species of zeolite, consists almost entirely of silica, lime, and water, apparently a particle of each, and two of water †. There is another very well known

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* It is easy to be conceived, that, by superficial loss or otherwise, the water in these minerals might be somewhat under rated. The analyses give the following numbers:

	True Ratio.	Analysis.
COMMON OPAL		
Silica, . . .	240^{3}	240
Water . . .	12^{1}	11.2—*Klaproth.*
HYALITE.		
Silica, . . .	160^{2}	160
Water, . ,	12^{1}	11—*Buchols.*
PRECIOUS OPAL.		
Silica, . . .	320^{1}	320
Water, . .	36^{3}	35.55—*Klaproth.*
MENILITE.		
Silica, . . .	80^{1}	80
Water, . .	12^{1}	10.4—*Klaproth.*
HYDRATE OF SILEX, from Pfaffenreith.		
Silica, . . .	80^{1}	80
Water, . .	48^{4}	43.6
or,		
Silica, . . .	160^{2}	160
Water, . .	84^{7}	87.2—*Schwitz.*

† Silica, . .	80^{1}	80
Lime, . .	40^{1}	38.2
Water, . .	24^{2}	24.6—*Kobell.*

mineral, named Table Spar, which contains little else than silica and lime. It seems extremely probable that lime should dissolve the silica, and that a united molecule should result, in which one particle of lime should be surrounded on its quinate parts by five particles of nascent silica, and this body unite with another particle of lime*. But as no two chemists agree in the results of the analysis of such minerals, except when they are guided by certain hypothetical views, to which their analyses naturally conform themselves, we need not be too curious as to the structure of the molecules of rare compound minerals, when we have no better guide than the residuary matter obtained by their destruction. Like carbon and hydrogen, the affinities of the earths for each other are such that a multitude of ratios may be established, all of which are natural; and it is only in the more abundant minerals that we need expect a simple structure. There are other minerals, such as the crysolite, olivine, and serpentine, which are almost wholly composed of silica and magnesia. The crysolite, analyzed by Vauquelin, seems to have consisted of a molecule of silex, with one of magnesia, on each of the four arms, two molecules being united by a particle of the oxides of iron †.

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* TABLE SPAR.

Nascent silica, .	$90^{\dot{5}}$	90
Lime, . .	$80^{\dot{2}}$	80.2 mean of the analyses of *Klaproth*, *Stromeyer*, *Rose*, and *Bonsdorff*.

	True ratio.	
† Silica, . . .	$80^{\dot{1}}$	80
Magnesia, . .	$104^{\dot{4}}$	106 *Vauquelin*.

FLUORINE.

In the Mineralogical System of Mohs, there is a genus named Fluor-haloide, including two species of very remarkable characters. One of these is rhomboidal fluor-haloide or apatite, which is a phosphate of lime; the other is octaedral fluor-haloide, and this is known to consist also of lime as a base united to a certain substance, of most extraordinary and terrific properties. As it occurs in nature, the mineral is beautiful and innocent, and fluor-spar is one of the prettiest things which the young collector finds in his cabinet. It usually occurs crystallised in tessular forms, which are sometimes very highly polygonal. Mr Phillips possessed seventy different sorts, and one, had all its faces been perfect, should have been included under 322 planes. The colours of the spar are also very fine, and have gained for it the names of False Sapphire, False Emerald, False Amethyst, and False Topaz. It is very abundant in the tin mines of Cornwall, and the lead mines of the north of England. In other countries also, such as Saxony, it is common, but in Scotland and many other places fluor is a rare mineral. The granular and imperfectly crystalline varieties are cut and polished into vases and such like pieces of furniture, and certainly Derbyshire spar is a very beautiful thing to look upon. Neither would one suppose that it contained any more formidable ingredient than marble, rock-crystal or a gem. But, on pouring oil of vitriol upon fragments of fluor contained in a glass retort, certain fumes are disengaged, which speedily dim the glass, and eat their way through it, and if the least quantity chances to touch the skin, the consequences are such as are thus described by MM. Gay-Lussac and Thenard: "Of all the properties of fluoric acid, the most extraordinary is its action upon the skin; scarcely has it touched it when it is disorganized. A strong pain is soon felt; the parts contiguous to the point of contact are not long in becoming white and sore, and a little after a blister is formed, whose walls are white, very thick, and which some time after contain pus. However small the quantity of acid, even when it is scarcely visible, these phenomena equally take place. Their development, however, takes place slowly. It is sometimes seven or eight hours after the contact when they are observed; and notwithstanding, the scald is still so severe as to occasion acute pain, take away sleep, and give rise to fever. Too many precautions, then, cannot be taken to preserve one's self against this acid, whether when wishing to repair the lutes through which it may be escaping, or when, having raised too much fire, the tube is melted, and one wishes to take it away; and, still more, when after the operation one wishes to transfer it. Oftener than once we have been severely hurt, and we have seen several young chemists hurt themselves still more grievously, although forewarned of all the dangers. There were particularly three whose forefinger and thumb could not be cured in less than a month, and yet these organs had only been a few seconds in contact with the acid in a state of vapour. It is more than probable that they had lost their two fingers, or at least had preserved them with difficulty, if a few drops had fallen on them. That which places this beyond doubt, is what was shewn by a little dog [*]" .... !

Now, it is very interesting to observe, that, in combining with silica, to which, in the early experiments, this substance would, of course, be exposed, it loses much of its virulence, and thus, in destroying the chemist's apparatus, it saves himself.

All the phenomena which it presents, seem to indicate that it belongs to the same series of forms as silicon, while, at the same time, it gives signs of a relationship to phosphorus. Although many minerals, when heated, phosphoresce, in none is this property more remarkable than in fluor-spar, and its natural connection with the phosphate of lime has been already stated. Phosphorus also acts upon glass, and the wound occasioned by its combustion is not a little analogous to that occa-

[*] Recherches Physico-Chemiques, t. ii. p. 11.

sioned by fluoric acid. There are three forms to which the mind is led from such considerations, which are externally isamorphous, and consist of a particle of phosphorus or sulphur, united to one of silicon on its pole, (Fig. 85). Their atomic weights are severally 14, 15, and 16, nor do the experiments which have been made on this formidable substance place it beyond doubt which is the true one. In the absence of satisfactory evidence, we may assume that whose weight is 15. The atomic weight of fluorine assigned by Berzelius is 15·006 + 2. This form seems the most probable, and consists of a particle of silicon with three of hydrogen, as in sulphur, phosphorus, boron, &c. &c., and a single atom on the other pole, as in phosphorus, (Fig. 58). When the oil of vitriol is poured upon the fragments of fluor in the alembic, and heat applied, the decomposition commences, sulphate of lime is formed, the fluoric principle comes over, and if the receiver be kept very cold, and the spar employed contain no silica, it condenses in the receiver (which must of course contain no silica), in the form of a limpid liquid. MM. Gay-Lussac and Thenard dropt a bit of potassium into this liquid, and there was instantly a violent detonation and a vivid combustion. The laboratory was filled with vapours, and nothing was left to examine. Having repeated the experiment in a more cautious manner, these chemists found that a remarkable quantity of hydrogen was generated, and a liquid remained, which fumed and became crystalline when exposed to the air. Distilled in a glass alembic, this crystalline mass yielded fluate of potassa, water, and fluo-silicic acid. It seems very probable that part of the fluorine is resolved into hydrogen and silicon, and that the liquid mass operated on consisted of quaternate molecules of fluorine, united in pairs by a particle of water. This water would afford oxygen to the potassium, and would disengage some hydrogen, but of this substance three particles would also result from each of fluorine destroyed. There seems nothing against the development of a hydro-fluoric acid analogous to sulphuretted hydrogen, &c. but perhaps it is not notably generated during the disengagement of the fluoric principle from fluor-spar.

The liquid fluoric acid dropt in water, like anhydrous sulphuric, or a red-hot iron, hisses, and no doubt improves its symmetry, by entering in single particles, instead of quaternate, into the concave poles of a particle of water (Fig. 66). This hydro-2-molecule weighs 42, and when hydrated by six particles around the equator, and probably one on each pole, is the molecule which is diffused in the solution in water. In the retort from which the fluoric matter has been disengaged, sulphate of lime is found, and experiments of this sort by Sir H. Davy and Berzelius assign the former 15·44, and the latter 15·2, as the quantity of fluoric matter combined with 40 of lime. Now, 40 being the atomic weight of lime, these analyses afford a very strong confirmation of the view which assumes 15 to be the atomic weight of fluorine or anhydrous fluoric acid.

Cryolite.—The fluoric principle, like phosphorus, is produced in the animal system, and, in union with lime, was detected by Berzelius as one of the constituents of bone. When, indeed, we consider its action upon the living fibre, we are tempted to conclude, that the virus of certain diseases which is developed in the system, by the original introduction of a few particles, thus disposing to their development in greater quantities, from nearly analogous forms previously existing, or natural to our organization, consists of forms perhaps intimately connected with phosphorus. But fluoric acid also occurs in the mineral kingdom, united in notable quantities to soda and alumina in the cryolite, and to cerium and yttria. These minerals are, however, extremely rare, and have hitherto been found only in Greenland and Sweden. The cryolite is from the former country, and is stated by Vauquelin to be composed in 100 parts of

		True Ratio.
Alumina, ...	24	24^1
Soda, ...	36	40^1
Fluoric Acid and Water,	40	42^2
	100	106

It has attained the name of Cryolite from its icy appearance.

Topaz.—This mineral is rendered interesting, not only on account of its value as a gem, but because it enters into the composition of certain rocks. From its analysis, it seems to consist of one particle of fluoric acid, one of silica, and five of alumina, or it is cyanite (as indicated by the analysis of Laugier) with a particle of fluoric acid added to each molecule. The topaz of Schneckenstein yielded

	Berzelius.	True Ratio.
Silica, . . .	80	80^1
Fluoric acid, .	19	15^1
Alumina, . .	128	120^5

Fluoric acid also occurs, in minute quantities, in mica, lepidolite, hornblende, apophyllite, wavellite, and others. But whether it always survives the rude treatment of analysis, or is discovered where it exists, may perhaps be questioned. In the laboratory, it forms two very interesting compounds with silica and boracic acid.

Fluo-silicic Acid Gas.

When sand or glass, or other siliceous mass, is mingled with fluor, and vitriol infused, a gas comes over, possessing very different properties from fluoric fumes. It does not corrode glass vessels, provided they be dry, nor is its action on the animal system so violent, though, as might be expected, it is still very destructive to animal life.

It has been already stated, that two particles of silex are requisite to form a symmetrical molecule, and that in mineral bodies it seemed very often to exist in binate molecules. There can be little doubt but it exists as such in those siliceous materials used to prepare fluo-silicic acid gas. Now, if such double molecule received a particle of fluorine on each of its six siliciferous regions, it is evident that a very symmetrical form would result. But on entering the gaseous state, it seems not improbable that this form should, sooner or later, break up into two, as in the case of phosphuretted hydrogen, and the gaseous volume be constituted of equal measures, or an equal number of acid particles, the one containing twice as much fluorine as the other, and both symmetrical. If we suppose no water present, one of the particles of silex will have a particle of fluorine on each pole, the other particle of silex, one on each of its four equatorial arms. Now, as to the specific gravity of this mixed fluo-silicic gas, it does not admit of a doubt, that the density of the particles will be only half as intense as in hydrogen, nitrogen, &c. It is therefore analogous to ammonia and the hydracids. The specific gravity of its two parts, then, will be ascertained in a rude way by dividing half their atomic weight by that of common air. Now the atomic weight of the heaviest, or that which contains four particles of fluorine, is 140, composed of 60 silex + 60, (4 × 15) fluorine. The atomic weight of the lighter gas, again, is 110, composed of 80 silex and 30 fluorine. Half the mean of these divided by 20.4, which is the atomic number for common air, gives a specific gravity of 3.06. But every pair of particles is subject to the incidence of six times three accidental atoms, for every particle of fluorine, like one of phosphorus or sulphur, has three concave regions exposed to the access of radiant matter, and, if fully charged, a quantity must be added to the specific gravity found by dividing the half of eighteen by the atomic number for common air, and this gives an addition of .441. Without a knowledge of its exclusive power, and to what extent it really does become charged, we cannot condescend more minutely; but on these data, the specific gravity of the dry gas fully charged with atoms, disregarding its exclusive power, might be 3.5. Judging from the low refractive power of silica, and the analogy of this gas with sulphureous acid, we should not be disposed to allow any thing for exclusive power; but in such ponderous unnatural gases, it seems to happen that the density is not always exactly a multiple of that of other gases; and besides, the presence of a little water would alter its specific gravity. Dr Davy found the specific gravity 3.5735, and Dr Thomson found it 3.6. So far, then, there is nothing unfavourable to this view of the structure of fluo-silicic acid gas. When it meets with aqueous vapour, those white fumes appear which seem always to be presented when a particle of vapour in the air perches upon a triædral pole. The acid has also such affinity for water, that between three and four hundred times its volume are absorbed by that liquid.

There can be little doubt, that immediately on coming in contact with water, the fluorine is converted into hydro-molecules, such as are met with in cryolite, and were supposed to exist when the free acid is dissolved in water. There will be a moment, then, in which the silex will partly, at least, be abandoned by the fluorine. Now, it is most natural to suppose that, during this evolution, a compound will be instituted, consisting of two particles of hydro-fluoric acid (Fig. 46.), one on each pole of a particle of silica, a regularly constituted bi-hydro-fluate of silica, analogous to the binoxalate of potassa. If we suppose all the fluoric acid to be engaged in this way, a fourth part of the silex of the gas must be set free, and being insoluble, must precipitate. There are only six particles of fluorine to two of silex, or 12 to 4. But 12 give rise to 6 hydro-2-molecules, which can only charge three of silex, so that the fourth must go down. 100 inches of the gas are found to weigh about 109 grains; therefore 44 will weigh about 48 grains. Neglecting every thing but the essential constituents of the gas according to the view here given, it is composed of silica and fluorine, in the ratio of 80 of the former and 45 of the latter; and, therefore, contains about 30.7 grains of silica, and 17.3 of fluorine. During absorption by water, then, $\frac{30.7}{4} = 7.67$ grains ought to be deposited, but the collection of the whole must be extremely difficult. Now, Dr Davy found, that when 44 inches of fluo-silicic acid gas were absorbed by water, 7.33 grains of silica were deposited, which is as near to this theoretical deduction as could be expected.

Berzelius mentions, however, that a third part of the silex originally in the gas is let go. In a form of so delicate a structure, it is only to be expected that different results should be obtained in different hands, more especially when we consider that a highly symmetrical molecule may result, composed of a double molecule of silex, with a particle of hydro-fluoric acid on each of its six poles, into which, were the whole solution to be resolved, one half of the silica in the gas must be let go.

But when the gas is exposed to absorption by water of ammonia, the whole of the silica is disengaged. In these circumstances, then, 44 inches, according to the structure here advanced, ought to discharge 30.7 grains of silica, and Dr Davy (with whose experiments those of Dr Thomson agree very closely) found that 44 grains absorbed by ammonia, let go 29.9.

This liquid substance is powerfully acid, reddens vegetable colours, and emits fumes when exposed to the air. It goes also, in some form or other, into union with bases. Its atomic weight, exclusive of water, which, however, is evidently essential to its constitution, is 140; water included, it is 164.

Fluo-boric Acid Gas.

Though boracic acid, a substance already noticed, in the molecular state, be highly fixed in the fire, yet, in individual particles, as often happens in other cases, it is of a volatile nature; and if we could conceive fluorine nascent along with it, it seems very highly probable that a particle of boracic acid should receive three of fluorine into its three concaves on the equator, and the compound particle thus generated ascend. It is a quaternate molecule of two nearly allied bases; and there are three particles of oxygen present, so that it will evidently be a very powerful acid. Like other analogous forms, the gas will be half the common density, and every particle will be subject to the incidence of nine accidental atoms. Its exclusive power will probably be very small, and its specific gravity may be approximated by comparing its atomic weight with that of common air. According to the view which has been assumed, its atomic weight is 88 composed of one particle, of boracic acid 43, and three of fluorine 45. To this, nine must be added, in attempting the specific gravity, and $\frac{45 + 43 + 9}{2} =$ 48.5 must be divided by 20.4, to find the specific gravity. This gives 2.377. Now, Dr Davy found the specific gravity of fluo-boric, or fluo-boracic acid, experimentally, to be 2.3709; and Dr Thomson makes it 2.3622; both of which agree as closely with that deduced by hypothesis as there is any occasion for.

This acid is very impatient of the gaseous state, and water absorbs about 700 times its volume. The resulting liquid is intensely acid, and of an aspect like oil of vitriol. It is extremely probable that a hydro-5-molecule is instituted analogous to phosphoric acid, in which perhaps the three particles of oxygen are even transferred from the pole of the boron to the equator of the water in which the boron is inserted, and the three particles of fluoric inserted into the oxygen. But whatever be the arrangement, the fluo-boracic acid unites readily with bases, is very caustic, carbonizes vegetable substances, and acts upon colours like oil of vitriol itself.

Fluo-boracic acid is not decomposed by being passed through a tube containing red-hot iron, but readily yields its oxygen to potassium. When heat is applied to a bit of potassium, with an atmosphere of fluo-boracic acid over it, combustion ensues, similar to what might be inferred to take place if an atmosphere of boracic acid only were over it. The resolution is very simple and complete. Every particle of fluo-boracic acid contains three of oxygen and three of fluorine; hence, when the potassium demands the oxygen, the three particles of caustic alkali generated are immediately supplied from the same particle of fluo-boracic acid, with three of fluorine. Thus three of dry fluate of potassa are generated, and one of boron is left in a disengaged state. Accordingly, MM. Gay-Lussac and Thenard, who explained the phenomena on these principles, found that no gas was generated by the combustion, and that the chocolate-coloured solid which replaced the metallic potassium, and which had absorbed all the fluo-boracic acid, when treated with water, resolved itself, without effervescence, into a solution of fluate of potassa and a residuary portion of boron. Fluo-boracic acid has been united to ammonia in three proportions. That which results from the union of an equal number of particles, or volumes, is a solid salt, resembling the other salts of ammonia. The others contain severally two and three particles of ammonia to one of acid; but they are liquids, and, on exposure to the air, they degenerate into the solid substance or that which contains a particle of each.

ARGIL. ALUMINA.

In the preceding pages it is asserted, that when three atoms of matter are united by their edges, a form results which is half a particle of calcium: when four unite, half a particle of silicon results; when five, half a particle of potassium. Six atoms, in like manner, united by two edges, give rise to a semi-particle of eminent symmetry and cohesion. But when two such are applied to each other, a form results which does not differ from a particle of water. A particle of water, then, by the expansion of its axis, gives rise to two such forms, and they may be united by twelve atoms, thus comprising a cavity, when separated by the proper distance, of a prismatic shape, having a truly hexagonal base, (Fig. 87). When we consider the extreme abundance of water, and the tendency of all such forms constituted of compressed faces to expand, when the faces can be relieved and symmetry sustained until a hollow form has been generated, we cannot but believe that the substance now contemplated must be very abundant, and it is natural to inquire if it be alumina. Next to silex, this substance is the most abundant on the face of the earth. It enters largely into the constitution of the primitive rocks, and it is equally the basis of clays, mud, and all plastic composts. It is deposited in immense quantities by lakes, and no doubt by the sea, forming strata of aluvium and silt of great extent every where. It also forms a constituent in most of the highly crystalline minerals; and several of the most beautiful gems, such as the ruby and the sapphire, are almost wholly composed of it.

According to this view of its structure, the atomic weight of alumina is 24, or double that of water; and, strictly speaking, it is an individual body, and has no base analogous to that of lime or silica. But if there is no mistake in the experiments, it must be admitted that the Hafnian chemists, by their vigorous treatment, succeeded in destroying alumina, and reducing its matter to some inferior state, in which it possessed the metallic lustre, but which still retained so much of the structure of alumina, that it recovered itself when matter was supplied to it. The earth alumina, in a state of powder, we should expect to possess the lustre and colour of pounded ice or opaque water, with which its polar regions are isamorphous, and, accordingly, it is a white powder. When reduced into the state which has been called Aluminium, it acquired the metallic lustre, as is the case with almost every opaque solid substance of a homogeneous nature, and not in a state of chemical neutralization. That the form which is here supposed to be alumina is not subject to the attachment of oxygen, we may readily believe, for it is a large body on which there is no region conformable to oxygen. That hydrogen should be given off during the resumption of the perfect form by aluminium in water, is only to be expected, if any thing at all is given off, for water is wholly hydrogen, and only developes oxygen when its presence is required. Whatever quantity of matter the aluminium might require for the restoration of its perfect state, that of the decomposed particles of water which was not required would be given off as hydrogen or radiant matter, the former of which only could be recognized by chemical tests. That a form with so large a cavity should, by violent means, be reduced into small forms, seems extremely probable. If the vapour of potassium were passed through it at a white heat, oxygen would, of course, be the substance into which that metal would arrange the matter it derived from it. Chlorine would demand another form. The decomposition of alumina would probably consist in the resolution of every particle into one of water, and an equatorial form, consisting of an annulus of twelve atoms, which is probably aluminium. It must be admitted, however, that this view of the structure of alumina derives no illustration from the experiments of M. Vöhler; but all other phenomena, and especially the natural habits and relationships of alumina, countenance it in an eminent degree.

Aluminic Hydrates, Salts, and Stones.

Alumina, according to the view now advanced, belongs to the ternate system; hence muriatic, acetic, phosphoric, and especially sulphuric acid, are those with which it ought to form the best salts, and the ternate arrangement ought to be manifest in the number of the particles of water.

Hydrates.—Two hydrates may exist, of eminent symmetry; one when a particle of water is on each pole of a particle of alumina, to which both poles are conformable; the other when there is only one particle of water on one pole. In this way, it is evident that any number of hydrated particles may be strung together in a fibre, and lateral particles of water, to the number of twelve, may be attached to the equatorial faces of each particle of alumina, and the whole will form a plastic mass. Now, "when alumina is precipitated from an alkaline solution, collected on a filter, well washed, and allowed to dry spontaneously on the filter in a dry warm room, a hydrate is obtained, which is composed of equal weights of alumina and water." (Thomson's First Princ. vol. i. p. 315). In this way we found that the hydrate of silica is procured, in which each of the four poles is charged with a particle of water. Here, again, is the alumina, having an equal weight of water, that is, two particles, or both its poles charged. By a long continued exposure to warmth, the half of this water disappears, and a hydrate remains, composed of a particle of alumina, charged with one of water. But to expel this altogether, a very strong heat is required. As the water between two particles escapes, these particles spontaneously approach each other, so as to occupy the space recently filled by the water, and to apply their angles to each other, which are equally conformable with those of water; and it appears, that after all the water has been expelled, this condensation goes on somewhat regularly. Hence a mass of clay, or alumina, suffers a permanent contraction from heat, and the amount of this contraction has been made use of as a pyrometer. Besides these, four other regular hydrates are possible, containing a greater quantity of water, in which three, six, nine, and twelve particles, severally, are attached to the equatorial faces; and there are two in which the quantity of water is less. The most symmetrical of these, or that in which three particles of alumina are attached to the alternate segments of a particle of water, is at once developed by exposing alumina that has been ignited to the air. It immediately increases in weight, and, in a dry atmosphere, it remains permanent when 72 parts, or three particles, have increased by 12, or become 84. The experimental result of Berzelius is, that 72 parts increases 11·16.

The hydrate of alumina is a substance of the greatest value in the arts. It forms the basis of bricks, tiles, fire-clay, crucibles, and all sorts of porcelain and stone-ware, and thus, after wood itself, is most serviceable in the domestic economy of life. It is also extensively used in the art of dyeing as a mordaunt, as it has a remarkable affinity for colouring matter. In this, as in most other relations, it seems to act the part of a sort of earthy water, which adheres to the water in the tissue of the stuff, and cannot be dissolved away.

Alum.—The best known salt of alumina, and that of the most extensive utility in the arts, is Alum, the salt from which the earth takes its name. It is usually procured by lixiviating certain sulphureous argillaceous slaty rocks, on which alum is naturally disposed to effloresce. The function of alumina, in these, and other salts and minerals into which it enters, is very analogous to that of water. The salts remain acidous; and, in the case of all the alums, of which there are several species, it is necessary to afford a nucleus for the crystalline molecules of some other salt, such as sulphate of potash, soda, iron, or ammonia. Around this, according to the number proper to the ternate acid, are three of vitriolate of alumina. The most common sort of alum is that in which one of sulphate of potash is associated with three of vitriolate of alumina, each of the particles of vitriolate of alumina bearing six particles of water, and one more, essential to the vitriol; further, there are probably three particles of water on the poles of the vitriols in union with the alumina, common to two such semi-molecules which are thereby united into one symmetrical body; and two particles of water more are on each pole of the symmetrical molecule. The investigation of such molecules, however, requires the aid of crystallography: they all give rise to a regular octaedron. According to this view, there are on one side of the equator of such a molecule three particles of alumina 72, one of potash 60, four of acid 200, and twenty-three and a half particles of water. Its real structure, however, may be very different.

	True Ratio.	
Acid, ...	200^4 . . .	200
Alumina, . . .	72^3 . . .	72·9
Potash, . . .	60^1 . . .	59·2
Water, . . .	276^{13} . .	275· *Thomson. Quoted in Henry's Elements*, vol. i. p. 607.

Besides this substance, in which one particle of alumina is on the pole of one particle of oil of vitriol, others are found in which the alumina takes the place of water. Thus there is an aluminous salt, composed of a particle of oil of vitriol with one of alumina on each pole, and a third, in which there are three particles of alumina to one of acid.

One particle of the former seems to serve as a nucleus for three of the latter, in the constitution of the mineral named Aluminite, 34 particles of water being occupied in the molecule [*]. The subsulphate of alumina and potash of Riffault seems also to consist of three particles of the ternialuminous sulphate; but the nucleus, instead of being a particle of the dialuminous sulphate, as in aluminite, is a particle of sulphate of potash; and the same analysis is applied to the alumstone from Solfa, near Civita Vecchia, used in the manufacture of alum (Mohs' Mineralogy, vol. ii. p. 68), though, in the specimen analyzed by Vauquelin, silex entered largely.

Phosphate of Alumina.—Phosphoric acid is another ternate acid, and alumina occurs in nature united to it, constituting the rare mineral named Wavellite. The specimen analyzed by Fuchs contained only alumina, phosphoric acid, and water, and the structure is very explicitly indicated by his analysis. The alumina, as usual, occupies the place of water. One particle forms the nucleus for a distribution of phosphoric acid, similar to that of the glacial acid, that is, a particle of alumina forms the nucleus, and three others cover the naked poles of the three particles of phosphoric acid, attached to the equatorial region of the central alumina; and besides these five particles of phosphoric acid 90, and four of alumina 96, there are six of water 72.

	True Ratio.	
Acid, . . .	$90^{\dot{5}}$	90
Alumina, . .	$95^{\dot{4}}$	95·3
Water, . .	$72^{\dot{6}}$	71·7 *Fuchs.*

Acetate of Alumina.—It is evident that three particles of acetic acid, attached to their particle of water, may be accom-

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[*] ALUMINITE.

	True Ratio.	
Alumina, . .	$264^{\dot{1}1}$	261·
Acid, . . .	$200^{\dot{4}}$	200
Water, . . .	$408^{\dot{3}4}$	408·7

Analysis of specimen from Newhaven, by Stromeyer.

mediated on the pole of a particle of alumina in a most symmetrical manner. But the number of acetates which might be generated by mixing the acid and base in due proportions, seems to be very great. A particle of alumina is capable of distributing symmetrically about it, almost any number of acetic particles up to fourteen, and Wenzel seems to have examined an acetate of the latter sort. That which consists of a ternate molecule of acetic acid and a particle of alumina, crystallizes in prisms, which adhere very firmly to the aluminous dish in which they form.

Acid, . .	66^3	66·6 or 62·5
Alumina,	24^1	24· or 22·5
Water, .	12^1	12· or 11·25 *Thomson.*

Muriate of Alumina.—Muriatic acid forms, with alumina, solid matter, very different from the chlorides, and not capable, by the ordinary methods, of being converted into a chloride. There are two muriates, one consisting of a particle of acid, with one of base and three of water; the other, analyzed by Bucholz, consisting of one of acid with five of water, which is the number proper to the acid when its pole is covered, united to two of alumina. There are many other substances which may be formed in the laboratory by the union of alumina and acids, but they are of little interest. Alumina is too weak a base for procuring very interesting results in the rapid and rude treatment of the laboratory. It is to nature that we must look for the highly symmetrical forms, of which alumina constitutes a part.

Aluminic Minerals.—Alumina and silex are, in the crystalline world, what hydrogen and carbon are in the vegetable. The number of their combinations seems to be as great as the specific forms to which they give rise are numerous. Although, as in the vegetable kingdom, there may be certain molecules, as, for instance, a double molecule of silica, which are introduced in great numbers in constructing crystalline forms; yet here and there, as fulcra and nuclei, single particles of one or other are, no doubt, introduced, and to detect the true chemical constitution of the great majority of mineral species, will probably require not only the most rigid and unprejudiced analysis, but all the aid of a crystallographic synthesis.

There are many, however, of the more notable crystalline bodies, which even the analyses now extant enable us to perceive that they possess a very simple structure. Thus that interesting mineral the Petrosilex[*] of Sahlberg in Sweden, indicates, by the analysis of Berthier, a structure analogous to that of Hyalite, the water being replaced by alumina.

Felspar[†], again, consists of one particle of silex and one of alumina, with one of potash to every four[‡]. Albite has the same composition, but the potash is replaced by soda, and stilbite seems to agree with them, the potash and soda of the others being replaced by lime.

In Analcime, again, the ratio of the earthy constituents are the same, but there is one of soda to every three particles. In some other minerals there is a double molecule of silex. Thus, Leucite has a double molecule of silica, three of alumina, and a fourth of potassa.

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[*] PETROSILEX.

	True Ratio.	Berthier's Analysis.
Silica,	160^2	160
Alumina,	24	24·5

[†] FELSPAR.

	True Ratio.	Analysis.	
Silica,	80	80	
Alumina,	24	25	Adularia by *Vauquelin.*
		24.5	Common Felspar and Labradorite from Norway by *Klaproth.*
Potash,	$\frac{60}{4} = 15$	15 nearly, *Klaproth.*	

[‡] ALBITE.

	True Ratio.	Analysis of Rose.
Silica,	80	80
Alumina,	24	23.5
Soda,	$\frac{40}{4} = 10$	10.8

In Meionite there is a single particle of silica with the same quaternate arrangement around it, three parts being alumina, and the fourth a particle of lime. But until the methods of crystalline analysis be improved, these views need not be extended.

ANALCIME.

	True Ratio.	Analysis of Vauquelin.
Silica,	**80**	**80**
Alumina,	**24**	**23.1**
Soda,	$\frac{40}{3} = 13.3$	**13.3**

COPPER.

We may resume the subject of metallic forms to illustrate the properties of two, which have been known from a very remote antiquity, and are still more extensively used in the arts than any other. These are Copper and Iron, the former of which receives additional interest from its utility in the docimastic art, while the latter seems to hold a place in nature inferior in interest and importance only to the radiant matter itself. Circumstances, afterwards to be mentioned, render it extremely probable that copper is a form composed of four atoms, inclosing a tetraedral cavity, with two particles of hydrogen applied to the two opposite re-entrant angles (Fig. 89). Its atomic weight is 8. But its form is much less parasitic than any of the other metallic bodies which have yet been noticed, and it may be preserved in the air in the metallic state. If we arrange these particles symmetrically one upon another, we shall find that filaments are produced; hence copper is a ductile metal. There is also an arrangement of edges very similar to that which obtains in sulphur, which may be connected with the similarity of their colours. But copper is also capable of giving rise to symmetrical quinate molecules (Fig. 90), whose atomic weight is 40; and hence it is sometimes met with in the ordinary tessular forms of crystallization. Native copper, however, or copper in the metallic state, is a rare substance, and it occurs more frequently in slaggy dendritic and mammillated masses than crystallized. The forms most analogous to copper are charcoal and sulphur. It is indeed externally isamorphous with two particles of carbon in a transverse position, and its relationship to sulphur is very distinctly seen when a number of particles are associated together. Copper, as it occurs in the arts, is always contaminated with these two substances, nor is it easy to free it from them entirely.

Oxides.

Copper can be retained with a pure metallic lustre for an indefinite time, only by preventing the access of oxygen. When exposed to common air, a surface of metallic copper becomes covered in the course of time with a green crust named Verditer, which is a carbonate of the oxide of copper. Three oxides of copper are possible, one in which two particles are on opposite sides of a particle of oxygen, and other two in which there are severally five and ten. In the first of these the oxygen is far from being charged; the latter two have excited much interest.

Peroxide.—That in which five particles of copper invest one of oxygen, as in potassa and lime, does not occur in nature in a free state as a crystalline mineral, but only as a product of the decomposition of more perfect forms. It constitutes the basis of the cupreous salts, and is named the Peroxide. Its atomic weight is 50 ($40^{\dot{5}}$ copper $+ 10^{\dot{1}}$ oxygen). It is a very useful substance in the analysis of combustible bodies, for it is not decomposed at a red heat, unless carbon or hydrogen, or some body having a stronger affinity for the oxygen than the copper, is introduced. But, in these circumstances, it parts readily with its oxygen, to generate with the combustible either water, fixed air, or pyragynic acid, as the case may be.

Protoxide.—The oxide in which the oxygen is completely invested, occurs in nature in a free state, constituting a crystalline mineral named Ruby Copper, or Red Oxide of Copper. Its forms are tessular, and by transmitted light it shows tints of a very deep red. Crystals of this substance are also frequently developed among the slags of copper-smelting furnaces. It may also be prepared for chemical purposes, by saturating the peroxide with metallic copper. Its atomic weight is 90 (80^{10} copper + 10 oxygen).

Sulphuret of Copper.—Sulphur and copper act upon each other with great vigour. When a disk of copper is made to touch one of sulphur, there is a powerful disengagement of electricity. When copper foil is exposed to the action of sulphur vapour, it burns spontaneously; and when three parts of copper-filings and one of sulphur are mingled, and heat applied, they unite with the production of much fire, though no oxygen be present. This sulphuret also occurs in nature somewhat abundantly, constituting a dark-coloured mineral named Vitreous Copper, which is one of the most valuable copper-ores. It consists of a molecule of copper and a particle of sulphur, and its atomic weight is 50 (40^{5} copper + 10^{1} sulphur), as has been found by analysis. There appear also to be two other sulphurets, one in which there are two particles of sulphur, and another in which there is a quaternate molecule, thus rendering the sulphur and copper equal in quantity. The greatest supply of copper used in the arts, is obtained from a brassy looking mineral, which is a sulphuret of iron and copper, afterwards to be noticed.

Rosin of Copper. Chloride of Copper.—Chlorine and copper may be made to unite in two proportions, and that which chiefly results when copper is burned in chlorine gas, being otherwise procured by heating copper-filings and corrosive sublimate, was known to Boyle, and described under the name of Rosin of Copper, from its resemblance to rosin.

It is not to be wondered at, that, when the chlorine is neutralized, the compound of chlorine and copper should seem to be a vegetable substance, for the general contour is that of particles of carbon symmetrically disposed. It is a compound of one particle of chlorine, and as much copper, as is in the protoxide, or ten particles, which may be accommodated five on each pole. Its atomic weight is 125 (80 copper + 45 chlorine) as indicated by analysis.

Cupreous Minerals.

Carbonates of Copper.—Copper and fixed air occur in nature united, but their affinity is weak and indefinite. The resulting carbonates are green and blue minerals, named Malachites, Verditers, Blue and Green Copper. One particle of peroxide is saturated by one of carbonic acid; and, in these minerals, water is also present, which is somewhat unusual in the stony carbonates. Vauquelin's analysis of common malachite gives 50 oxide of copper, and 14.5, instead of 15, as the fixed air present. Berzelius has shewn that the oxide may be made to receive from 13.5 to 17 of the acid as the temperature of the water is raised in which it is precipitated.

Phosphate of Copper.—Copper and phosphoric acid are found united, constituting a very rare mineral, named Prismatic Habroneme Malachite or Hydrous oxide of copper. Its structure, like that of the carbonate, is extremely simple, consisting of a particle of copper, one of phosphoric acid, and one of water, or 50 peroxide, 18 acid, and 12 water; the numbers indicated by the analysis of Lunn, being 50 peroxide, 17.9 acid, 11.9 water. Its atomic weight is 90. Like most other cupreous earthy bodies, it possesses a green colour.

Arseniates of Copper.—There are several compounds of copper and arsenic acid, which, in the natural system, are found beside the phosphate.

1. *Prismatic Liriconite of Professor Jameson. Octaedral Arseniate of Copper or Linsenertz.*—This is a very rare mi-

neral, of a sky-blue or verdigris-green colour, which has been found almost exclusively in certain mines in Cornwall. According to the analysis of Chenevix, it consists of 160 peroxide of copper, 28.6 arsenic acid, 71.6 water, which are, to a decimal, the atomic weights of 2 particles peroxide, 1 of acid, and 6 of water.

2. *Radiated Acicular Olivenite, or Oblique Prismatic Arseniate.*—This mineral is found along with the preceding. Externally it seems very deep blue or black, but internally it is blue. The analysis of Chenevix gives 50 peroxide of copper, 28 arsenic acid, and 14.8 of water, the former two numbers being exactly the atomic weights, and the last only a little more than that of one particle of water.

3. *Prismatic Copper-Mica. Rhomboidal Euchlore Mica. Rhomboidal Arseniate of Copper.*—This is a mineral of a bright green colour. It occurs in similar situations with the preceding, and consists, according to the analysis of Vauquelin, of 50 peroxide of copper, 55 arsenic acid, 21.7 water. Now, one particle of peroxide of copper is 50, two of arsenic acid is 56, and two of water 24. There are also other arseniates of a less simple structure, and resembling the arseniates of the laboratory, in containing arsenic acid in a quinate hydro-molecule. Thus a mineral analyzed by Klaproth, and included by Mohs in the species prismatic olive-malachite, yielded 150 peroxide of copper, 133.2 arsenic acid, and 10.35 water. Now, 140 of arsenic acid, and 12 of water, is a quinate molecule, and 150 of peroxide, are three particles.

Salts of Copper.

Blue Vitriol.—Copper readily unites with oil of vitriol, and a sky-blue solution results, from which fine crystals, of the same colour, but generally very deep, are obtained. These crystals are also met with in nature, deriving their origin from the decomposition of sulphuret of copper. The solution is decomposed by metallic iron; so that, if a plate of iron be introduced into a solution of the blue salt, it is speedily covered by metallic copper. The acid and oxide may also be separated by heat. Like the other salts of copper, blue vitriol possesses a very simple structure. A particle of oil of vitriol bearing three of water on its equator, and one on its naked pole, along with one of peroxide of copper on the other pole, constitutes the saline particle; and two such, united by a particle of water, which is common, form the crystallizing molecule. There is, therefore, 50 parts of copper, 50 of sulphuric acid, and 54 of water, on each side of the equator *. Perhaps, however, the molecule is in reality much more complicated, and consists of four or seven parts on each side of the equator, as seems to be usually the case with the crystalline molecules of the vitriolates. When pure potassa is infused into the solution, in smaller quantity than is requisite to engage all the acid, an insoluble precipitate falls, which is composed of a particle of vitriol with one of peroxide on each pole.

Nitrate of Copper.—Nitric acid attacks copper very vigorously, dissolving the metal with the evolution of nitrous gas. The salt which results is of a very deliquescent and corrosive nature. It consists of a particle of peroxide and one of acid †; but a very regular structure is not to be expected when the salt possesses such characters, and more especially when the nitric acid is so far from being saturated by the oxide, that, when a part of the acid is driven off by heat, or engagement with an alkali, the peroxide becomes engaged on the quinate region of the acid, and every particle of acid sustains five of peroxide, and probably five of water on its other pole. This nitrate, with excess of base, is an insoluble green precipitate,

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*	True Ratio.	Berzelius' Analysis.
Oxide, . .	50	50
Acid, . . .	50	49.13
Water, . .	54	56.3

†	True Ratio.	Berzelius' Analysis.
Nitric acid, .	70	70
Peroxide, . .	50	52

which, to judge from different analyses, appears not to possess a very uniform structure *.

Verdigris.—When a disk of metallic copper is exposed to the fumes of acetic acid, it is speedily covered by a crust of a green colour, and a poisonous quality, known by the name of Verdigris. This green crystalline matter consists of three acetates of copper, which may be easily separated from each other. The simplest is that on which one particle of acetic acid is united to one of peroxide. It has been called the Triacetate of Copper. The molecule consists of two such particles united by a particle of water, which receives the hydrogerent poles of the acetic acid into both its concave poles. It consists of 50 oxide of copper, 22 acetic acid, 6 water †, on each side of the equator. Another salt consists of two particles of acetic acid, one on each pole of a particle of oxide, and one of water on each hydrogerent pole of the acid. It has been named the Subsesquacetate of Copper. It contains oxide 50, acid 44, water 24 ‡. The third is a salt which may be obtained by dissolving the whole green crust in vinegar. It forms large and beautiful crystals, possessing a slight metallic taste, and, like the other salts of copper, it is of a poisonous quality. Its structure is analogous to that of most acetates, and consists of a ternate hydro-molecule of acid and a particle of oxide; it consequently contains 50 of oxide, 66 of acid,

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*	True ratio.	Berzelius' Analysis.
Acid, . .	70^{1}	70
Oxide, . .	250^{3}	244
Water, . .	60	56

†	True ratio.	Berzelius' Analysis.
Oxide, . .	50	50
Acid, . .	22	21.1
Water, . .	6	6.6

‡	True ratio.	Berzelius' Analysis.
Oxide, . .	50	50
Acid, . .	44	41.4

and 12 of water*. In forming so many definite salts with acetic acid, copper shews its relationship to carbon. The result of the combustion of all its salts, is a black carbonaceous-looking powder or peroxide.

Ammonia possesses a certain power of dissolving some cupreous precipitates, and entering into union with them, giving rise to solutions and crystals of a fine blue colour. It seems to act the part of water, if we could conceive the solvent power of water increased. The structure of the ammoniurets has not been investigated.

IRON.

It has been shewn, that a particle of alumina consists of atoms circumscribing a cavity, which is a hexagonal prism; that the base of potass consists of atoms circumscribing a pentagonal bipyramid; that the base of silica consists of atoms circumscribing a tetragonal bipyramid; that the base of lime consists of atoms circumscribing a triangular bipyramid. What form shall possess such eminence in nature as to be composed of atoms circumscribing a tetraedral cavity, which is the form of the ultimate atom itself? This is iron (Fig. 91.), a substance so universally diffused in nature, that it would be difficult to find any natural body whatever, in which we could positively say that there was no particle of iron in it. But without inquiring at present into its distribution over nature, let us for a little attend to its physico-chemical relations.

Its atomic weight is 4. Like radiant matter itself, it is destitute of an axis; and being thus liable to have either a positive or negative state induced upon it, by position, it will exert an almost unlimited range of affinity. But though it have no poles and equator, it has two sets of angles, which are

*	True ratio.	Ure's Analysis.
Oxide, . .	50	50
Acid, . .	66	66
Water, . .	12	10.2

dissimilar, and will exhibit the attractive fluid in consecutive states. The quantity of this fluid, which must be proper to a mass of iron, must be immense; for, supposing the molecules are insulated from each other by carbon, or otherwise prevented from neutralizing each other, every particle has four acute angles for the one polarity, and four obtuse angles for the other. The magnitude of a particle, and its specific heat, are very small. In a very small volume, an immense number of atomic angles must be included, in such a state of quiescence as is most favourable for the intense activity of the attractive fluid; yet it is so destitute of natural form, to give direction to the polarity of the particles, that it is easy to believe that a polarity may be induced in any direction to which the form of the mass may dispose. When the continuity of a mass of particles or molecules of iron is interrupted by an admixture of oxygen, carbon, phosphorus, or sulphur, in due proportion; that is, when the attractive fluid is prevented from neutralizing itself by a free transmission within the mass, the whole exhibits the same phenomena as if it were one particle, its polarity depending on its form.

In examining iron with a view to discover its singling angle, we are at a loss to find lines symmetrically related to each other; but it is very natural to suppose that a ray of light will be singled most perfectly when it is incident with its edges, parallel to the two edges in the iron which lie in the same plane. A ray thus incident will form, with the ray reflected in a similar manner, an angle of 141° 3′ 28″. The angle of incidence, then, will be 70° 31′ 44″, at which, according to this view, the most remarkable singling effect should take place. Now, the singling angle of iron, as far as observations have been made, is stated at from 70° to 71°; but it is difficult to see how iron could have a polarizing axis, or could single the light like water, glass, or other such body, composed of particles possessing an equator and axis.

Iron, as it occurs in the mineral kingdom, is most generally united to oxygen, constituting iron-ores, ochres, and ferruginous minerals. These, when treated with extreme heat, yield up their iron in a metallic liquid state, the earthy matter floating upon it as glass and scoriæ. The iron thus reduced, varies very much in quality. When it filters through a long course of coke, it becomes dark coloured, coarse grained, and soft. By repeated fusions, again, without causing it to run through coke, it becomes brighter in its colour, close grained, and hard. In all cases, it is more or less brittle, according to the rapidity or slowness with which it is cooled. Crude or cast-iron, in the solid state, possesses rather a less volume than in the liquid state; but solid cast-iron floats on liquid cast-iron like wood upon water, and even when pressed to the bottom of a pot of liquid metal, it rises to the top. These phenomena indicate that we are not acquainted with the specific gravity of iron, when it is not affected by the terrestrial magnetism.

Denate Molecule.—Iron is evidently capable of three modes of molecular arrangement, very different from each other; and a mass of iron will possess different properties, according to the arrangement in which it exists. In a state of fusion, when the most free motion of the particles among each other is admitted, and when, in consequence of the heat, the repulsion among the particles will be greatest, we may naturally infer that the particles will be arranged in the largest, or denate molecules. This is a very symmetrical form, including an icosaedral cavity, or a cavity conformable to a particle of carbonic oxide. Fig. 93 represents it as viewed along the axis, in which only five of the atoms are introduced.

The atomic weight of this molecule is 40. A mass composed of such bodies would certainly be brittle or crystalline in its texture; and there is every reason to believe that cast-iron consists chiefly of such molecules, mixed with other sorts and portions imperfectly developed.

When the heat of fusion is long sustained in a quantity of crude iron, it begins to undergo a change analogous to that of sulphur in similar circumstances; it loses its fluidity, and becomes a soft ductile mass. This change is accompanied with the development of certain points in a state of very vivid combustion, and with the disengagement of a large quantity of inflammable gas. This gas burns with a blue flame, like carbonic oxide or hydrogen. When we consider that the cavity of the denate molecule of iron is a mould for carbonic oxide, and that carbon and oxygen both abound in iron, and probably free atoms of matter, which will adopt any form to which they are induced by their position, we will readily believe that this burning gas consists partly of carbonic oxide and partly of hydrogen. Besides hydrogen, carbon, and of course manganese, it is impossible to avoid believing, that magnesium, phosphorus, sulphur, arsenic, and especially calcium and silicon, must be developed in the iron in small quantities. Calcium is that form which is most nearly related, and may be regarded as two particles of iron, each wanting an atom, united on their deficient region. But its symmetry is very small compared with that of silicon, and it is reasonable to conclude, that, by a continuation of the heat, the calcium would be separated into iron again, or, by the accession of two atoms, be expanded into silicon.

By stirring the mass of liquid iron, so as to facilitate the escape of the gaseous matter, and the new arrangement of the particles of iron which is taking place on the destruction of the denate molecule, the mass continues to become more and more viscid, and ultimately, however much the heat be urged, it refuses to return to the fluid state. Such is the first part of the process in which crude iron is reduced to the state of malleable iron. When it has been brought to this state, it is removed in a soft ductile mass, and violently compressed by engine hammers. During this process, the impurities are still farther pressed out of it, and it assumes the densest arrangement of which the iron is capable.

Fibrous Molecule.—This we may suppose to be that of particle to particle, from which there results a twisted filament, analogous to those of copper. One filament is of extreme tenuity, but it is not symmetrical on opposite sides;

and such filaments will evidently group together until they constitute a symmetrical filament, which must be a body of extreme tenacity. That such is actually the structure of hammered iron, has not only been inferred from its ductility and tenacity, but by observation with the microscope, under which its fibrous structure has been rendered distinctly visible. When a rod of iron in this state is exposed to a violent heat, the hot fibres repel each other, but do not break, and they flow down around the solid central mass like syrup. Two masses of iron in this state may, by hammering, be incorporated into one; and the interlacement of the fibres thus effected, called *welding*, imparts as much tenacity to the place where the junction was made, as if the bar had been originally continuous.

Ternate Molecule.—It does not appear that without the introduction of some ferment to dispose to a new arrangement of parts, the fibrous structure can again be destroyed. But such a ferment exists in carbon, to which iron in ternate molecules is conformable. When, therefore, a quantity of hammered iron is enclosed in a strong heat along with carbon, the iron suits itself to cover the carbon, as oxygen would, if air were admitted; thus, in a manner, performing the office of combustion to the carbon.

The form in which it exists when thus moulded to carbon, is the ternate molecule (Fig. 92), which is, of all, the most easy and natural state of aggregation. The atomic weight of this molecule is 12: in its centre is a cavity conformable to a particle of hydrogen; and on each side of the centre, but on the polar aspects, are three moulds for carbon, while, on the three equatorial aspects, there are three regions conformable to oxygen. This wonderful substance, then, in a single ternate molecule, exhibits types of all the most important substances in nature—three cavities which are moulds of radiant matter, one that is a mould of hydrogen, six fit for the reception of carbon, and three for the reception of oxygen, while the atomic axis is a particle of calcium. Iron, in the state of these ternate molecules, along with that quantity of carbon which may chance to have been absorbed into it during the fermentation, constitutes Steel, a substance of extreme value in the arts, in consequence of the range between hardness and softness, of which it is capable, depending on the degree of rapidity and slowness with which it is cooled. In a state expanded by heat, the crystalline arrangement seems to predominate over the fibrous, and, by rapid cooling, the mass seems to be fixed in this position.

Oxides of Iron.—If iron could be united with oxygen in a gaseous state, so that the two substances could be presented to each other in definite volumes, it seems reasonable to believe that five oxides at least might be formed. One, when a single particle of iron is in the pole of one of oxygen; a substance which would perhaps be with difficulty distinguished from vital air itself; another, when one ternate molecule of iron is attached to a particle of oxygen; a third, when five particles of iron are arranged around one of oxygen; a fourth, when two ternate molecules are placed on opposite sides of a particle of oxygen, as the metallic parts in soda and magnesia; and a fifth, when all the ten faces of the oxygen are covered by ten of iron. The ratio of saturation of the oxygen, however, lies between the two last; and although the occurrence of some of the others has introduced considerable perplexity into the investigation of the oxides of iron, yet these are the two which are possessed of most interest.

Red Oxide, Peroxide.—When a bright metallic surface of iron is exposed to pure dry air, no union takes place between the vital air and the metal. The cohesion of the particles of iron among themselves is unfavourable, and the occupation of the poles of the vital air by radiant matter, prevents the immediate incidence of the oxygen upon the iron. But if vapour or water be present, then particles of the fluid are apt to place themselves upon the metallic surface, the pole of the water being conformable to one of the four parts of a particle of iron. But the affinity of iron for oxygen is very great; hence it induces the water into the form of oxygen, and the hydrogen escapes. There is now an oxide of iron in the nascent state; and whether we conceive it to consist of five particles of iron around the equator, and one in the pole, or of two ternate molecules of iron on opposite sides of the equator, the ratio of iron and oxygen will be the same. The latter condition of the oxide is the most symmetrical and most analogous to other forms, and this we may regard as the form of a particle of peroxide of iron. Each of the particles thus formed now unites with a particle of water in a manner similar to soda, potassa, magnesia, lime, and others. Six such particles unite into a molecule, that is, a true hydrate, and thus the metallic surface is covered with a tissue, subject to the incidence of fixed air. This ferruginous tissue is well known by the name of Rust: it is a hydrate of the peroxide of iron, with more or less fixed air. The same substance may be immediately generated by several chemical processes in the laboratory. The atomic weight of this oxide is 34, and the ratio of iron and oxygen is 24 and 10, or 100 parts of iron, by being converted into the peroxide, will weigh 142, supposing the concave poles of all the particles to be free from atoms, to the incidence of which they are liable. Were they all charged by an atom, which is the limit, 100 parts would weigh, in the state of peroxide, 146·6. Now, Bucholz converted 100 parts of iron into peroxide, and found that they weighed 142. Hassenfratz obtained 142·224 in one experiment, 145 in another; Gay-Lussac, 142·35; Berzelius, 144·2; Thomson, 142·6 in one experiment, 144·76 in another.

The peroxide of iron, when freed from water, carbonic acid, and other bodies, is a bright red powder; hence it is often called the Red Oxide, or Saffron of Mars. As it is usually procured from the decomposition of the vitriolate of iron, or green vitriol, it is also often called Colcothar of Vitriol.

This oxide occurs in nature very abundantly united to water, or acids, or both. With water it forms the hæmatites and ochre; the former of which are valuable as ores, the latter as pigments. In the hæmatites, three particles of peroxide are usually attached to the alternate segments of a particle of water. The ratio of peroxide and water is therefore 102 and 12, as was ascertained by Daubuisson, who found in the analysis of this ore of iron from 82 to 84 of oxide, and from 11 to 14 of water. When the water is increased, so that there is a particle of water to every one of oxide,—a structure analogous to the true hydrates,—the mass is friable, has a light colour, and constitutes ochre. In ochre, then, there are 34 parts of oxide, and 12 of water, which agrees with the analysis of Ludbeck, who found from 84 to 86 of oxide, with from 12 to 14 of water. Ochre is abundant in nature. When fully hydrated, it is of a yellow colour; and as the water is expelled, it becomes gradually more red as it approaches the state of colcothar of vitriol. Hence, by various roastings, various pigments may be procured from one natural substance. Thus it appears, that in nature, the peroxide, in which the oxygen is rather in excess, is united into molecules by water.

Black Oxide, Protoxide.—But a particle of oxygen is not fully charged with iron when in the state of peroxide. If we suppose it to receive a particle more of iron on one pole, its ratio will agree with the composition of anvil scales, as analyzed by Berthier; for the iron will be to the oxygen as 100 to 35, while he found 34.5 to the same quantity of iron. But this is a form which evidently could perform no interesting part in the economy of nature; and on the incidence of an acid, would immediately degenerate into the peroxide, by letting go the particle of iron on the pole. No number of particles of iron less than ten could give rise to a form of such symmetry as might be expected in nature. But from this a body of great elegance results, externally isamorphous with a particle of cast-iron, or a denate molecule, already described. This is the protoxide, black oxide, or martial ethiops. It occurs abundantly in nature, but in it the oxygen is perhaps as much overcharged by iron, as in the peroxide it is undercharged; and this oxide is met with formed into molecules, not by water, like the peroxide, but by oxygen. Like the other, it also enters into union with acids; and more especially, along with oil of vitriol, it constitutes that very interesting salt named Green Vitriol, or Copperas. Its atomic weight is 50, and the ratio of its iron and oxygen is 40 and 10, or 100 and 25,—numbers almost agreeing with the determination of Boyle, who found that 100 parts of steel-filings, by being kept in a cupel under a muffler for two hours, acquired an accession of 27.8 to their weight, degenerating at the same time into a calx *. Many attempts have

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* In another experiment, this admirable man excluded the air by luting the crucibles together, and found that 100 parts of filings now gained only, in an hour and a half, 1.24 parts. Besides this, he prepared many other oxides, some of which were wonderfully perfect. Thus he found that 100 parts of tin, by becoming protoxide, increased 12.5 in weight; Gay-Lussac having found 13.5 parts. He performed a number of admirable experiments on oxides and sulphurets, and came to the very same conclusions as are commonly ascribed to a date a century later. Thus he says, " For whereas it is commonly supposed that, in calcination, the greater part of the body is driven away, and only the earth, to which chemists add the fixed salt, remains behind;—whereas these notions, I say, are entertained about calcination, it seems that they are not well framed, and do not universally hold; since, at least, they are not applicable to the metals our experiments were made on. For it does not appear by our trials, that any proportion worth regarding of moist and fugitive parts was expelled in the calcination; but it does appear very plainly, that, by this operation, the metals gained more weight than they lost; so that the main body of the metal remained entire, and was far from being either, as a peripatetic would think, elementary earth, or a compound of earth and fixed salt, as chemists commonly suppose the calx of lead to be......Whence I conclude that the calx of a metal, even made, as they speak, *per se*, that is, by fire, without additament, may be, at least in some cases, not the *caput mortuum* or *terra damnata*, but a magistery of it. For, in the sense of the most intelligible of the chemical writers, that is properly a magistery, wherein the principles are not separated—but the bulk of the body being preserved, it acquires a new and convenient form by the addition of the menstruum or solvent employed about the preparation. And not here to borrow any argument from my notes about particular qualities, you may guess how true it is,

been made to ascertain the composition of this oxide, by the volume of hydrogen disengaged during the solution of a known quantity of iron by dilute oil of vitriol. In an experiment of this kind, Dr Thomson found that 100 parts of iron in becoming the protoxide, detained a volume of oxygen, which, estimated as vital air, weighed 27.5 parts. But it unites to the iron as oxygen. Hence 27.5 is $\frac{1}{11}$th too much, and the real quantity of matter united to the iron is $27.5 - 2.5 = 25$. Another method is that which was pursued by Gay-Lussac, of precipitating the oxide from its engagement with an acid, and weighing it. By these means he found that 100 parts of iron, in the protoxide, are exactly united to 25 of oxygen,—a result identical with that ob-

that the greatest part of the body, or all the radical moisture, is expelled in calcination, which therefore turns the metal into an arid infusible powder, by this, that I have several times, from calx of lead, reduced corporal lead. And I remember, that, having taken what I guessed to be but about a third or fourth part of the calx of lead, produced by the third experiment, I found, by a trial purposely devised, that, without any flux-powder, or any additament, but merely by the application of the flame of highly rectified spirit of wine, there could, in a short time, be procured a considerable proportion of malleable lead; so little was the arid powder, whence this was reduced, deprived, by the foregoing calcination, of the supposed radical moisture requisite to a metal." His experiments are very numerous; and, after having mentioned that he had broken all his cupels and commodious glasses, where he could not repair his loss, he mentions his conclusions:—" And the third (which is the principal), that it will probably excite you, and your inquisitive friends, to exercise their sagacious curiosity in discovering what kind of substance that is, which, though hitherto overseen by philosophers themselves, and being a fluid far more subtile than visible liquors, and able to pierce into the compact and solid bodies of metals, can yet add something to them that has no despicable weight upon the balance, and is able for a considerable time to continue fixed in the fire."—(See his Experiments on the Powderable Parts of Flame, &c. Boyle's folio works, vol. iii. p. 340, *et seq.*) —How much occasion is there to regret, that it is the fashion of our day to read new books only, and to quote each other, as if the world began with us, forgetting men of such science, such moral and intellectual glory, and such a perfect English gentleman, as Mr Boyle. Yet, perhaps, it is prudent not to leave it to posterity to celebrate our age.

tained by the other method. In this oxide, however, there is an excess of iron, and its particles have a constant tendency to unite in pairs, by the medium of a particle of oxygen. This new oxide may be formed by inclosing a coil of fine iron within a porcelain tube, and transmitting steam through it, when hot, until the steam cease to be decomposed. The ratio of iron and oxygen is 80 and 30, or 100 and 37.5, as exactly found by the discoverers of this substance, Gay-Lussac and Thenard. These philosophers believe this oxide to constitute the beautiful minerals, named Specular iron-ore, and Magnetic iron-ore.

Sulphurets of Iron.

Iron Pyrites, Sulphuret of Iron.—If a piece of hot iron be rubbed on a roll of sulphur, a compound of iron and sulphur falls in drops; and if iron-filings, sulphur, and water, be mixed in due proportion, so violent an action sometimes ensues, that their union is accompanied by fire. Sulphurets of iron are also very abundant productions of nature, constituting common and magnetic iron-pyrites.

Common pyrites is a beautiful brass-yellow crystalline mineral, which occurs in masses and tessular forms. Every particle of sulphur (Fig. 46.) has three equatorial regions, conformable to three of iron; and three particles of sulphur thus charged, and aggregated around a particle of sulphur, as a nucleus, may constitute a molecule of iron-pyrites. Or, it may be that the four particles of sulphur constitute a quaternate molecule, and three ternate molecules of iron are attached, one to each of the particles of sulphur, which are in similar positions, or to the three conformable regions of the fourth. In either case, the ratio of the sulphur and iron is 40 and 36. Now, the mean of Hatchett's analyses of iron-pyrites, in dodecaedrons, and in smooth and striated cubes, gives 40 sulphur, and 36.4 iron. This molecule, as might be expected from its beautiful structure, demands the powers of nature and the stillness of the mineral strata for its production. The artificial sulphurets are rude substances, giving off fetid air, or sulphuretted hydrogen, when acted on by water and an acid. The artificial sulphuret makes a nearer approach to the magnetic iron-pyrites,—a mineral of a bronze colour, metallic lustre, and slightly magnetic properties. Its crystalline development is far less perfect than that of common pyrites. It readily fuses, and is acted on by acids, yielding sulphuretted hydrogen. Some varieties contain six molecules of iron, or double the quantity of the first; others, again, seem to have a different composition. The analyses of Hatchett and Stromeyer indicate that the mineral varies in composition. The molecules of the magnetic sulphuret seem also frequently to be mingled with those of the common pyrites, which is more nearly in the ratio of quiescence.

It has already been shewn, how naturally sulphur is developed, where successive particles of hydrogen are presented to each other. It will now be seen, that, after hydrogen, iron is the form which is most easily generated. The abundance of iron-pyrites, then, in nature is not to be wondered at. It is often the substance into which organic substances are most immediately resolved during their mineralization. Thus in peat-moss, the leaves of plants are frequently seen, of which the nervures are replaced by iron-pyrites, in a manner so beautiful, that it seems as if they had been injected with brass.

Arsenical Pyrites, Mispickel.—There is a pyritic mineral, of a silver-white and steel-grey colour, which occurs not unfrequently, both in beds and veins, accompanied by the ores of silver, lead, and tin. It is sometimes worked as a silver-ore, in consequence of the quantity of that metal which it contains, and it yields white arsenic at the same time. It appears from the analysis of Stromeyer, that it contains a septenate molecule of arsenic, formerly described, six particles of sulphur, and apparently nine ternate molecules of iron. The iron and sulphur are in the same ratio as in the magnetic pyrites analyzed by Hatchett. The molecules must be very complicated, and no doubt vary in different specimens.

Chlorides of Iron.—Chlorine is capable of entertaining molecules or particles of iron on one pole (or on the concave regions of the equator), or five particles on both poles. Hence there are two chlorides of iron. That which contains ten particles, and corresponds to the protoxide, is obtained by decomposing, in a cautious manner, the protomuriate of iron (a green-coloured salt resembling green vitriol), and igniting the dry matter. The chloride resulting, named Ferrane, is a grey variegated mass, with metallic lustre and lamellated texture. Its atomic weight is 85, and its chlorine and iron are 45 and 40 respectively. Now, Dr Davy who analyzed it, found the chlorine 45, and the iron 39.6, which is very near the truth, though it will not conform to the atomic weight of iron ordinarily assumed. The other chloride, named by Sir H. Davy Ferranea, is generated by burning iron-wire in chlorine gas. It is a beautiful volatile substance, of a yellowish-brown colour, and high degree of splendour. At a temperature a little above the boiling point of water, it assumes the gaseous state, and on cooling sublimes into small iridescent plates.

It seems to contain the same quantity of iron as the peroxide, and to consist of a ternate molecule on each pole. Or it may contain five particles on one pole, and one on the other. According to either view, its atomic weight is 69, composed of 45 chlorine and 24 iron, the analysis of Sir H. Davy having yielded 45 chlorine, and 23.2 iron.

Iron Salts and Minerals.

Carbonates of Iron.—It has been already stated, that rust consists of peroxide of iron, water, and fixed air united together. But it is the protoxide which occurs most abundantly in nature united to fixed air, and the resulting carbonate is found in various states of purity of composition, and texture, from the argillaceous or clay iron-stones to a crystalline mass, which is a pure carbonate, analogous in its structure to calcareous spar and others. At first sight, indeed, the more crystalline varieties of carbonate of iron or sparry iron resemble carbonate of lime not a little. Its greater specific gravity, the different angles of its rhomboidal fragments, its blackening in the blowpipe, or by continued exposure to the sunbeam or light, sufficiently distinguish it. Its atomic weight is 80, of which 50 are protoxide, and 30 fixed air. Bucholz analysed a very fine specimen from Eulenloh in Bareuth, and found it composed of 50 protoxide, and 30.2 fixed air. There is not in this case, as in the carbonate of lime, any range for the results of analysis, for the fixed air presents its convex poles externally, which are not subject to the incidence of atoms. This mineral is a very valuable ore of iron. It is met with in nodular masses, and in beds by itself, and it often constitutes the gangue of other ores. There is another carbonate which has been examined by Bergmann, in which only one particle of fixed air is present to every one of oxide, and which is therefore analogous in its structure to the carbonate of copper. Its atomic weight is 65, composed of 50 oxide and 15 fixed air; Bergmann having found 50 and 15.6.

Phosphates of Iron.—The protoxide of iron occurs in nature united to phosphoric acid, forming a rare and sometimes crystalline mineral, of a blue or indigo-colour. It is met with in primitive countries, and also in situations contiguous to the bones of quadrupeds, whence it obviously derived its phosphoric acid. The constitution of most of the specimens that have been analyzed, indicates a structure analogous to the carbonate. A highly crystalline variety analyzed by Stromeyer, yielded 50 protoxide, and 37.6 phosphoric acid, the true quantity being 36, on the supposition that it consists of two particles of acid, and one of protoxide. An artificial phosphate may also be readily prepared, in which the protoxide of the natural mineral is replaced by the peroxide. It is the persequiphosphate of Dr Thomson, and consists of two particles of acid 36, one of protoxide 34, and five of water 60; the numbers in the analysis of Dr Thomson being equivalent to 36 acid, 34.2 peroxide, and 61.2 water.

Arseniate of Iron.—Arsenic acid occurs in nature, united to protoxide of iron in two proportions, and in both the quinate hydro-molecule is involved. The first is analogous to one of the arseniates of copper, and constitutes a dark green coloured mineral, which usually occurs crystallized in cubes. It seems to consist of three particles protoxide of iron, one quinate molecule of arsenic acid, and six of water. Were this its structure, it would contain 150 oxide, 140 acid, and 72 water. The analysis of one sort by Chenevix yielded 168.7 protoxide, 140 acid, and 70 water. The other sort is also included in the species Hexaedral Lirocone-Malachite or Cube-ore, and consists of a quinate hydro-molecule of acid, four of protoxide, and three of water, or 140 acid, 200 protoxide, and 48 water. Chenevix' analysis gives 140, 205.5, and 47.4. Like the other arseniates, however, the number of combinations seems to be very great.

Green Vitriol, Vitriolate of Iron.—Of all the salts of iron, none possesses greater utility in the arts, or in chemistry, or performs so interesting a part in nature, as copperas or green vitriol. It is generated abundantly by the decomposition of iron-pyrites, and is extensively used for yielding oil of vitriol, and other substances used in chemistry and the arts. It is also generated during the action of diluted oil of vitriol on metallic iron. When newly prepared it is a highly crystalline body, of a green colour and much transparency. But when exposed to the air, it parts with its water, and its protoxide, passing to the state of ochre or peroxide, gives a ferruginous aspect to the crystals. They are very soluble, and possess a styptic taste.

A particle of vitriolate of iron consists of one of oil of vitriol, one of protoxide, and six of water. But the molecule seems to be very large. We may suppose it to be thus constructed; six particles of the vitriolate, each with its six particles of water, arrange themselves around one which is in the centre, and has six aspects for their reception; and two such bodies, fronting each other and uniting, constitute a symmetrical molecule. It is, however, deficient in poles, and it appears that two particles of oil of vitriol, without being charged by protoxide, place themselves at each extremity of the axis to constitute poles. Thus there is an uncharged particle of vitriol in the crystal for every seven of the salt. Such a structure agrees in every figure with the analysis of Mitscherlich, which is given to the second place of decimals. But it seems possible that a particle of sulphuric acid may vary in weight from 50, which is its naked weight, to 56, which is its weight when fully charged with atoms, according to the manner in which the analysis is conducted. When a solution of green vitriol is heated in the open air, and aided by the infusion of nitric acid, its protoxide passes to the state of peroxide. If no vitriol were present, each of these would take down a particle of water, and there would simply be a precipitate of the hydrate of the peroxide, or of ochre. But as vitriol is present, six particles, instead of grouping by themselves, group around one of oil of vitriol; and there results a salt, long ago named by Berzelius Sulphate of the Peroxide with excess of base, and by Dr Thomson Pertetrasulphate. The oil of vitriol seems to be hydrated by a particle of water on each pole, and three on the intervals of the equator; so that there are altogether 50^{1} parts of sulphuric acid, 204^{6} peroxide, and 72^{6} of water,—the numbers of Berzelius' analysis being 50, 203 2, and 69.5, severally. But besides this salt, which falls down in the solution of green vitriol, in the condition which has been mentioned, another sulphate remains dissolved. It is simply a sulphate of the peroxide, analogous to that of the protoxide, consisting of a particle of each, or 50 acid, 34 peroxide. It is the persesqui-sulphate of Dr Thomson, whose numbers are equivalent to 50 acid, and 33.33 peroxide,—the oxysulphate of others. This salt is soluble in alcohol, as well as water; but it cannot be made to crystallize, except when constituted in molecules somewhat analogous to those of alum. In that mineral we found that octaedral crystals resulted, when a particle of sulphate of potash was supplied to every three of vitriolate of alumina. In the present case, octaedral crystals may be obtained, by supplying a particle of oil of vitriol to every three of the vitriolate of the peroxide, the molecule having apparently twenty-eight particles of water, or seven to each of the four parts. These crystals were obtained by Mr Cooper; they are transparent and colourless, and possess a taste, as well as crystalline form, resembling alum. The numbers which have now been stated, require

	True Ratio.	Cooper's Analysis.
Sulphuric acid, . .	$200^{\dot{4}}$	200
Peroxide of iron, .	$102^{\dot{3}}$	100
Water, ...	$336^{\dot{2}8}$	330

There are many other salts of iron, and it might be easily shewn how perfectly their structure is indicated by analysis, according to the atomic weights here proposed. Thus, the nitrate of the peroxide, towards which the nitrate of the protoxide tends, is simply a compound of one particle of peroxide on one pole of a truly hydrated particle of nitric acid; and it is curious to observe how faithfully the atomic numbers of Dr Thomson, which are so different from those here advanced, indicate the true structure. Thus, under the belief that the persesquinitrate is composed of 1½ atoms of nitric acid, 1 of peroxide, and 8 of water, he states its composition, nitric acid 10.125, peroxide 5, water 9; which are severally equivalent to 70, 34.5, and 61.2; the true numbers being 70, 34, and 60. The subpernitrate which follows in his work *, seems to consist of two senate hydro-molecules of peroxide, or molecules constituted by a particle of water in the centre, with six of peroxide around, and one of nitric acid. One would ex-

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* First Prin. vol. ii. p. 330.

pect a nitrate analogous to the nitrate of the peroxide of copper, with excess of base.

Prussian Blue.—Besides these, there is a very interesting combination of iron and cyanogen, which, with peroxide of iron and water, forms Prussian Blue. There are two regions on a particle of cyanogen, or hydrocyanic acid (Fig. 77), either of which is conformable, in an eminent degree, to five particles of iron. This compound body, with a particle of peroxide of iron on its pole, and one of water, probably on the other, which is hydrogerent, seems to constitute Prussian blue. According to this view, ferrocyanic acid contains a quantity of iron equal to that of the nitrogen which it yields on decomposition, along with the quantity of carbon proper to cyanogen, and one particle of hydrogen. Such is the structure assigned by Dr Thomson's analysis. Including the hydrogen, its atomic weight would be 52, composed of 30^{i} cyanogen, 20^{5} iron, and 2^{i} hydrogen. Prussian blue would consist of 52 of acid, 34 of peroxide of iron, and 12 of water. Now, Mr Porret's analysis gives 53 acid, 34 peroxide, and 12.3 water. The acid, in a free state, is a structure of extreme delicacy, but is very valuable from the varied tints which it yields when a solution of the ferrocyanate of potassa is infused on metallic solutions. These matters, however, require investigation, and I cannot help believing, that if the structure of such delicately constituted bodies is ever to be discovered, it will only be by the method introduced in this work, or some one equivalent to it, and not by a chemical destruction of them, which, though it be often a true analysis, is often but ill entitled to the name of analysis at all.

On the Natural Distribution of Iron.

Such are some of the forms of combination in which iron is most frequently found in nature and in the laboratory; but to trace the modes of its existence minutely would require volumes. It is perhaps generated at the first breath of the youngest creature in the world, and it is abundant in the oldest granite. After radiant matter itself, doubtless the distribution of iron is the most universal. It constitutes a large proportion of mica, hornblende, and clay-slate, which, with quartz and felspar, that are seldom altogether free from iron, compose almost the whole crust of the earth. Besides this, there are immense deposites of iron-ore, both in primitive and secondary countries; and some very learned philosophers have thought that the quantity of iron in the interior of the earth must be immense, without so good evidence for such a hypothesis as is afforded by the views advanced in this work. It enters also as colouring matter into most bodies which possess colour. It is found in the ashes of vegetables, and in the fluids of animals. Ferruginous dust and pyritic hailstones are sometimes showered down from the skies; and from these regions there have fallen hundreds of masses, chiefly composed of iron, several of which are of great magnitude. This reminds us of some curious consequences arising from the structure of iron, and let it be remarked, that the following observations apply only to the substance treated of here. The reader may affirm that my views in reference to iron are absurd, as it will be very natural for him to do if he only consider iron as a mass of metal, but certainly they are the very phenomena which must be displaced by such a substance as that now treated of.

When iron has been once fused into a mass, so admirable is the cohesion of the contiguous particles, and so small a specific heat is each of them capable of sustaining, that it is highly fixed in the fire, nor has it been yet raised to the temperature at which it boils. It appears, however, that an iron ball cannot be often heated red hot without losing weight, and it is evident that a departure of atoms which affects the balance, must arise from the evaporation of a most innumerable host. But even disregarding altogether the evaporation of sidereal particles from the surface of the earth, the ease with which radiant matter can be transformed into iron, whose hollow nucleus is isomorphous with it, will induce us to expect it wherever a force exists, tending to develope it. When, therefore, we consider the prodigious quantity of iron every where diffused, even on the surface of the earth, and the probabilities of so much more deeply seated, we should almost expect that Siderogen, or individual particles of iron, should form a constituent part of the atmosphere as well as radiant matter or Hylagen. This tissue must also be generated at the surface of the earth by the sunbeam, in a way which has been already attended to when treating of the opening up of particles of Hydrogen in page 207.

But the condition of such an aërial fluid would be very different from that of the gross parts of the atmosphere, vital air and nitrogen. It may be questioned whether any means that have yet been taken, would be adequate to its discovery. Even supposing its particles contiguous, of all conceivable media it must be the most rare. The smallest integral part consists of a tessular tissue, the siderial particles being so disposed as to form, on a general view, the edges of a pentagonal dodecaedron, twenty particles being implied in the constitution of one form. This becomes, again, the nucleus around which twelve are associated, and the cavities are so large, compared with the quantity of matter which constitutes the frame-work, that a fabric of iron rendered solid in this arrangement would be incredibly light. It would also be perfectly invisible, and occasion no refraction, for rays of radiant matter may be continued through it in all directions at angles of natural symmetry; and it would permit air and water to pass through its vesicular structure as freely as if they were passing through space. It would be a tissue more ethereal than light itself. But, at all terrestrial temperatures, such a tissue would not possess its particles cohering. It would exist in the aëriform state; and I do not know whether we could detect it, even though it existed around us of considerable density. Elasticity, weight, refraction, and chemical union, are the ordinary indications of aëriform media. But if its symmetry were once destroyed by compression, it would recover it again only by a very slow process, analogous to crystallization; for it is not the mutual repulsion of the atoms which keeps them at this unusual distance, but their positions of symmetry demanded by their attractions, and the restoration of it would be a slow process, as in other cases where volumes are expanded in a similar manner. As to chemical union, we should almost expect that some experiment might be invented to discover it if it were actually present, though it might exist without interfering with the ordinary experiments, or anyhow indicating its existence. But farther, it is to be remarked, that every particle of this siderial medium must be fixed in its position by the terrestrial magnetism; and to cause the atoms leave their natural positions and unite, would require no ordinary effort. On the other hand, the transmission of gases through it would be most free, and phenomena would be presented by them as if it were not present. Of whatever density, it would evidently not be ponderable, for it is fixed in position by the terrestrial magnetism; and though, perhaps, a volume of it, when of unusual density, might ascend so as to find its true place in the magnetic arch, it never could depress the scale of the balance in which it existed. To invent experiments to discover these things would be extremely difficult; for we could not exclude all matter from a given space, except the siderial medium, supposing that we were capable of generating a volume of it, and the buoyancy which it might occasion would very probably be exactly balanced by the increased density of the radiant medium, which would be generated at the same time, and which nothing prevents from depressing the balance. Neither would it, except in very peculiar storms, be agitated, so as to occasion a sensible pressure or wind, being still more fixed than the radiant medium, and admitting a most free passage of the air and light through it in all directions.

It would be possible to sustain these views by many arguments, and to shew that phenomena at the surface of the earth, which now remain unaccounted for, might derive from such a hypothesis a very happy explanation. But it is not necessary to suppose that it possesses a density at the surface of the earth, such as that we should regard it as an object of chemical research. An independent force exists to cause it gravitate upwards as other bodies gravitate downwards; and the sky must be its region of greatest density and repose. It must form a canopy at considerable elevation above our atmosphere, spreading from both terrestrial magnetic poles, and thus including the world in a gossamer tissue of iron particles. We are accustomed to think of iron as a gross, heavy, body, according to which opinion, it seems eminently absurd to speak of iron in the sky; but the views advanced in this work lead us to believe it as more intimately related to radiant matter than any other body. It is the great storehouse of the attractive, as the radiant is of the repulsive principle.

The existence of this tissue in these lofty regions, a consequence that cannot be avoided from the principles advanced in this work, is indicated by the production of meteorites, which, it is perfectly manifest, are often seen on fire in regions very far above the limits of our atmosphere, and are found to be composed of the very elements which would be most immediately developed in the siderial canopy. These are, besides iron, hydrogen, (and of course water), nickel, magnesium, silicon, and sulphur; now these are the very bodies that constitute the bases of all those meteorites which are not almost wholly iron; but in many regions of the world, huge masses of meteoric iron itself are found. The oxygen which is contained in their composition indicates water, for into this element water must be resolved in the presence of such substances. No view which has as yet been advanced to account for these interesting bodies, is in any degree satisfactory. They are seen on fire in regions very much above those where the atmosphere, granting to it a greater elevation than has ever been contended for, must be already incapable of generating combustion. But they are burned bodies, and when they are seen on fire are as evidently burning as any other bodies which are reduced more or less to the state of a calx by uniting with oxygen. They could not be projected from volcanoes; for of all the substances projected from volcanoes, there are none possessing a similar composition, though, in consequence of the fusion of the common matter of both, pyroxene is frequent in both. It might be supposed that the large masses come from the planetary spaces in consequence of some convulsion; but there is a continuous series of meteorites from masses weighing tons to impalpable powder, to all of which a similar origin must evidently be ascribed; and we could not imagine that the dust could come from distant planets. By this consideration the Moon is also relieved from the charge of throwing these stones at the Earth with an efficacy which is very marvellous, when we consider that the earth is always as high above the moon, as the moon is above the earth. It is well that philosophy is not always accessible to the vulgar. The admirable Humboldt, who has seen many thousand aerolites in a single night, contents himself with believing that they certainly are not generated in our atmosphere. And I cannot help thinking, that the view which has now been advanced explains their origin and composition so naturally, that their occurrence affords a satisfactory indication of the existence of the siderial medium, which has been introduced here as a consequence of the nature of iron. But if such a canopy existed, ought it not somehow or other to be visible?

When we consider the very feeble action upon light of such a tissue as the siderial canopy, we could not expect it to be visible in the day-time, during which the intervening atmosphere must be so much brighter; but there does not seem any reason why, in very pure states of the air, it might not at certain hours be visible during the night, sustaining a feeble light over the whole sky by the solar illumination received on its concave side; or producing a luminous caustic, visible in certain regions and at certain hours, from the light received on its upper side. In consequence of the penetration of the sun's rays through the diurnal side, some of them which pass the earth's limb ought to be reflected from the canopy, which possesses more or less the form of a concave mirror; and this accords with observation. For, certainly, during the darkness of night there is a light in the sky between the stars, of which they are not the cause, and which cannot be explained by atmospherical refraction. But for some time after the sun has set, or before he rises, his rays must be incident upon the convex side of the canopy, on which, could they be seen, they would probably produce such crepuscular phenomena as are observed near the disk of Venus; but a part of them ought also to be reflected to the surface of the planet, or the Earth; for such is the structure of the siderial medium, that there are reflecting planes in all directions. This phenomenon must be most fully developed where the siderial canopy is most symmetrical and perfect, that is, in the neutral region, or over the equatorial parts of the earth; and though our data are not sufficiently minute to enable us to investigate the caustic that would be formed, it would certainly present the very phenomena of the zodiacal light. The siderial canopy, however, is perhaps not every where insulated from the earth, but may be connected at both poles. For we could conceive that the magnetic force, by which it is solicited, might enable it to penetrate into the denser parts of the atmosphere, though, doubtless, like the radiant medium, its structure will become more perfect as it gains the regions of serenity above. It is a conductor of electricity, yet its parts are not so immediately contiguous that electricity might be transmitted without luminous phenomena. We might therefore expect that towards the magnetic poles, where the siderial canopy and arches are incident upon the Earth, luminous streams should frequently be seen tending up the canopy, or transverse bands of light, indicative of regions where the electric transmission along the magnetic meridians is stopt, and takes its natural course at right angles to the magnetic axis. The phenomena of the aurora fulfil these conditions perfectly. Upon the whole, this siderial apparatus, to which I am almost forced by the views now advanced of the atomic structure of iron, which, it has been seen, are very applicable to the chemical relations of the metal, instead of being an intrusion upon nature explains many of the most striking, and hitherto inexplicable, phenomena of meteorology.

The existence of this siderial canopy enables us also to explain the phenomena of the magnetic needle, for, like every other polarised line or edge, the quiescent position of the needle must be parallelism with that to whose influence it is subject. It is therefore in every latitude found parallel to the arch of the siderial medium above it; and hence, in all latitudes except that of the magnetic equator, dips more or less to the north or south. The local distribution of iron, however, in the crust of the earth, and other circumstances presently to be noticed, prevent that perfect parallelism which would result if the globe possessed a perfectly regular magnetic structure, like one of Gilbert's Terrellæ. And it is well known that the same disturbance might be induced any where, altogether independently of the terrestrial magnetism, except in so far as we identify it with the terrestrial electricity.

These views might be illustrated at greater length; but it seems to me, that arguments for this canopy are not necessary, because its existence must follow from the atomic nature of iron. But shall we say, that all the siderial matter connected with our planet is thus disposed of, or that that which is generated at other planets, is confined to regions near their surface? Iron is, of all bodies, the most abundantly diffused in the earth. We see that it is the permanent form most nearly allied to the radiant matter which occupies the celestial spaces. We see that its existence is compatible with any temperature; we can scarcely avoid concluding, that, where the radiant medium is so dense as to constitute a photosphere, an immense quantity of siderial matter must constantly be generated. At all events, it is but fair to believe, until we find reason to think otherwise, that iron is as abundant at other planetary bodies, as it is at that with which we are acquainted. Nothing has yet been discovered by astronomy that would justify us in assuming that the constituent substances of other stars are different from those of the earth. The nature of iron, however, which is unresolvable by fire, would lead us to infer, that, in planetary bodies of very high temperature, iron, silicon, &c. would abound, instead of water, carbon, and other unexpanded forms, or forms with suppressed faces. Every circumstance which can be imagined induces us to believe that the heavenly bodies, whose matter is of a fixed nature, such as the stars, the sun, and the planets, severally contain a quantity of siderial matter or iron, to the development of which a high temperature and great magnitude must be very favourable. As they all rotate, they must possess magnetic poles more or less nearly coincident with their poles of rotation. Hence a planet existing within the sphere of the action of the sun will, immediately on the development of a sufficient quantity of iron in it, be embraced by the sun. From his poles two arms of siderial matter must be extended, which will be incident towards smaller ones stretching up from the poles of the planet, and thus the two will be united, and the sun will necessarily cause the planet to describe ellipses around him, in the direction of his own rotation. The same mechanism explains the phenomena of double stars. It is a singular feature of the modern philosophy, that astronomers should have universally rested satisfied with the belief that there is no physical cause for the revolution of planets around the sun, while they occupy themselves most assiduously in seeking physical causes for every other phenomenon.

From what has been already said, when treating of water, it follows, that a comet is a body in a different state of development from a planet. The siderial canopy and arch are found only at the latter. This constitutes it a member of the solar system, and implies that it consists of a substance of a fixed nature, and contains a variety of crystalline substances. From such a state of things two very important results follow: *First*, a planet must revolve round the sun in the direction of the sun's rotation, in such a way that the square of its periodic time shall be as the cube of its distance; and, *secondly*, the limits of its position in space must be in the plane of the sun's equator, all the magnetic axes of the system tending to be parallel. It is well known that the squares of the oscillations of a magnetic body (on completing the arcs, the squares of the revolutions) are proportional to the force by which it is moved; while it is also proved that the magnetic force emanating from both poles of a magnetic axis, and affecting a body susceptible of being attracted by that axis, varies as the cube of the distance between them; hence the squares of the periodic times, and the cubes of the distances, are both proportional to the force, and to each other; so that this law of Kepler follows physically from the known laws of magnetic movement, as well as mathematically from the properties of central forces. But not less necessary than that their revolution should be in one and the same direction with the sun's rotation, does it follow that they should tend to be found only in the region of the solar magnetic equator, for far on either side an unipolar magnetic state would be induced, incompatible with the individuality of the planet's magnetic axis, and the symmetry and existence of the siderial canopy and arch. In the region of the solar magnetic equator, however, the planet's magnetic connection with the sun remains only as a cause of revolution. There a portion of ferruginous matter, such as a siderial canopy or satellitic arches, may exist without being torn away to either pole of the sun. The occurrence of planets near the plane of the solar equator, is a simple exhibition of the law of symmetry educed by the same forces as produce other symmetrical forms, and the limit is, also, that their axes should be parallel to that of the sun. But we know well that several accidents may be induced upon a surface to reverse the poles of a body, which, were it to happen at any planet, would gradually effect a complete semi-revolution of the axis. It is, therefore, not less in accordance with these views, that several of the planets should have their axes nearly parallel to that of the sun, than that Herschel should have his axis at present nearly transverse to it. There is every reason to believe that such changes must take place with extreme slowness. In the Earth the tendency to parallelism has been observed already in a very sensible diminution of the obliquity of the ecliptic; but the same might happen from other causes, if those conditions actually exist which are assumed in the hypothesis of simple gravitation. It would be possible, chiefly in consequence of the researches of Professor Hansteen, to point out a great many indications of a connection between the terrestrial magnetism and the positions of the heavenly bodies. Thus, the terrestrial axis is decomposed into two, which may mark the axes of the solar and lunar arches. There is also a regular monthly variation in the magnetic intensity. The terrestrial magnetic poles are believed to recede in the same direction, and with the same angular velocity, as the equinoctial points. When the Earth is in the region of the perihelion, the magnetic intensity is stronger than when it is in the aphelion. The magnetic needle acknowledges the influence of the sun upon the earth (independently of his light and heat, for the same effect takes place at great depths), and the northverse pole moves to the west during the time of the most intense solar action, as is usual in electro-magnetic experiments, when the southverse pole is the positive electric pole. But experiments in the terrestrial magnetism have hitherto been so much confined to the northern hemisphere as to render it advisable, in the mean time, not to insist too much upon these analogies. It may only be remarked further, that the aurora, which is no doubt a portion of the siderial canopy, rendered visible by the transmission of electric light, is most frequent about the two seasons when the Earth is in its ascending and descending magnetic node, when the symmetry of the terrestrial axis is most perfect, being then bisected by the neutral plane; and the same is said to be the case with the zodiacal light, which, as has been stated, is a portion of the same canopy, rendered visible by reflecting through it the sun's light some time after he has set and before he rises. To these remarks are to be added those which have been already made respecting the action on the movements of the heavenly bodies, arising from the structure of the medium of light.

Thus, during the investigation into the chemical constitution of bodies in this work, some remarks have fallen to be made regarding the mechanism of the solar system. The chief conclusions connected with these remarks are,

1. That comets may exist in any region, and proceed through the celestial spaces in the same direction as planets, or in a contrary direction, or any otherwise whatever.

2. That planets can only continue to exist in a certain zone of space, of limited breadth, including the solar equator.

3. That planets can only revolve in the direction of the sun's rotation, and satellites in the direction of their primaries.

4. That the medium of light in which the planets move possesses a structure which tends to induce and sustain their rotations and revolutions in their orbits in the same direction.

5. That the intensity of the light and heat produced by the sunbeam at the surfaces of the different planets, does not decrease in the subduplicate ratio of their distance from the sun, but is most probably regulated by the same law as that which expresses their gravitation towards him.

These conclusions, to which we have been accidentally led by the investigation of the constitution of matter and chemical phenomena, are in no degree at variance with the Principia of Newton, or any thing founded on the laws of central forces. It only requires a substitution of a physical mechanism instead of the conception of a mechanical impulse to adapt the demonstrations commonly received to the state of things advanced in this work. But such views, touching current opinions to the quick, ought only to be insisted on in posthumous works, when their author is beyond the reach of suffering.

BOOK IV.

OF

ANIMALS AND PLANTS.

OF SENSIBILITY.

> "Lapides crescunt.
> Vegetabilia crescunt et vivunt.
> Animalia crescunt, vivunt, et sentiunt."

Such is the beautiful climax by which Linné, with his own peculiar felicity of contrast, has characterized the three kingdoms of Nature in his admirable Philosophia Botanica. And though doubtless we oftner hear, in our day, of the division of Nature into the inorganic and the organic kingdoms, I cannot but regard the classification of the Swedish naturalist as at once more ancient and more natural.

In the preceding pages cause enough has been shewn why a group of mineral particles, not yet arranged symmetrically, should accomplish all that is implied in the word *crescunt;* nay more, it is evident, from the laws of atomic action which have been illustrated, that, after a group of particles had attained to their most symmetrical positions, any change in the physical circumstances of the mass, *if it possessed a delicate structure*, might occasion such a phenomenon as might be expressed by the term *decrescunt*. The word *vivunt*, then, applied by Linné to the vegetable kingdom, if supposed merely to express evolution and decay, exhibits nothing very strange to us. But the term *sentiunt*, which is used to characterize the animal kingdom, implies something altogether novel.

We have examined the action to which the atomic structure of matter gives rise, in a multitude of substances most dissimilar to each other, such as light, water, air, phosphorus, nitrogen, vital air, iron, silica, carbon, and many others. But in every instance the phenomena resulting were strictly mechanical, such as could be anticipated or explained by the knowledge of a few laws of motion and polarized action. They consisted exclusively in movements tending, by the action of certain mechanical laws, to improve the physical condition of the substance which moved, by causing it to approach towards a spherical form. Certain it is, however, that in a large class of beings, their bodies, composed of those very substances which we have examined, are further possessed of the wonderful power of feeling, and of moving their organs in directions quite contrary to those to which they must be solicited by genuine atomic forces. Nay, besides this power of feeling and of producing movements of sensibility, they also possess a knowledge of their own existence, a power of contriving and executing schemes, which are never performed by nature, and of moving and shaping matter into unnatural forms according to what they call their *will*. The observation of such phenomena as these, to which this section chiefly relates, introduces us now, as it were, into a new creation; for these are phenomena obviously of a nature quite different from the movements of atoms; and we are at first sight led to conclude that an animal must be composed of some very noble and superior sort of essence, whose action consists in feeling and thinking, which is embodied in an atomic structure, for the purpose of connecting it with the material world around, and for enabling it to execute its designs. Such, in review of what has already been shewn in reference to the structure of the world, seems to be the most legitimate conclusion respecting the constitution of animals. But when we observe the phenomena of the animal kingdom more in detail, we are apt to lose our *prima facie* confidence in this opinion; and finding the perfection of mind and body in animals always keeping pace together, we feel disposed, by such a coincidence, to suspect that the phenomena of sensibility and perception must really, some way or other, be ascribed to the atomic structure of these animals; and that, strange as it may seem, that counteraction of natural atomic movements, of which, from first to last, during the whole tenor of their life, they are guilty, can be nothing else than a certain atomic insanity, to which matter becomes subject when made hot in their central parts. If mind be an atomic function at all, we must admit that it is an atomic insanity; for hitherto we have found, and found so uniformly, and so often, as to entitle us to assume it as an universal law, that every movement, every function of atoms whatever, tends to the improvement of the atomic mass which these atoms constitute. Sensibility and cogitation, however, waste and dissolve our bodies, often rendering them unfit for their own organic activities. In constituting mind, therefore, atoms, it must be confessed, are working quite contrary to their legitimate and good habits; and if mind be an atomic function at all, then we must admit that it is an atomic insanity.

Is this strange atomic action, then, (which must not be disbelieved simply because it is strange), proper to every atom constituting a sensorium or mind; or, is it the resultant of the whole group, a phenomenon depending solely on relative position, each atom taken by itself being a simple atom, possessing no other specific properties but those which have been already ascribed to atoms universally?

If a mind be proper to each atom individually, the little bodies which fill all space, and constitute the radiant medium, can be nothing else than so many animals, so many minds, each invested with his own little pyramid for a body on which he sits, most truly like an ancient priest on his tripod, the subtile atmosphere around serving him for breath, or the matter of inspiration, which certainly it might do, better than any thing that could be procured at Delphi; and this is so far well; for, if we provide a body to the mind, it is but discreet to find breath also. Or if any one prefer to place the mind of the atom in its interior, which happily my demon disposed me to conjecture might be hollow, in a page during the printing of which the ensuing investigation was not contemplated, I will make no objection; for not only do we commonly find mind attached to central parts, but, in this instance, in particular, there seems almost a necessity for the atomic mind to possess such a retreat. The shattering which the monad must sustain in the sunbeam must be quite dreadful. To be tossed backwards and forwards 458,000,000,000,000 times, every second, from the beginning of time to the consummation of all things, is indeed a fearful destiny for any one; and it is much to be wondered at, that, in these circumstances, the radiant atoms, if they really have minds, can be in so good humour as to favour us on every occasion with those beautiful forms which they pourtray during the torturing experiments of physical optics.

But if it be said, that the minds of the radiant atoms are too simple to suffer or to possess any sensibility whatever, then their action, perhaps, consists in thinking; or if it be justly said, that it is absurd to expect cogitation in a mind that is incapable of feeling, then their action may perhaps consist in the exercise of some spontaneous power, different from any of the actions of matter hitherto detected, and yet neither feeling nor cogitation, but merging into either, in the proper circumstances. The lowest mental power which we can conceive any body having mind to possess, is that of moving itself spontaneously, that is, contrary to the natural movements of its molecules. Hence, were our hypothesis good respecting the rudimentary mind of the atom, the phenomena of physical optics ought to vary at different times, and in different places, according to the mutual sympathy, the fancy, fashion, state of feeling, run of radiant opinion, or march of intellect among the atoms which encircle the observer. But even though there be very considerable differences in the results of observations at different times and places, I fear it will not readily be granted that they arise from swarmings, and other social phenomena, occupying the atoms of the radiant medium experimented upon. On the other hand, there seems no reason to deny the common opinion, that the movements of the parts of the radiant medium are the most exquisitely passive and mechanical of all known phenomena, and are so calculable by geometry, that nothing durst be ascribed to accident, which gives at least a possibility for the interference of mind. It must be admitted, then, that the whole amount of the positive evidence is quite opposed to the hypothesis, that each particular atom of the universe has a mind of its own,—a hypothesis which, though it has had ingenious advocates, it is difficult to discuss, without a latent feeling of the ludicrous, scarcely to be controlled by the disposition to be grave.

If these atoms have not minds of their own, and it be still maintained that mind is a function of atoms, the mental phenomena must arise from the grouping of atoms, and must depend upon relative position, every atom having that intrinsic quality which gives rise to sensibility and cogitation, when atoms are properly grouped for performing these functions.

The simplest state of atomic relationship which we can imagine is the Torricellian vacuum. Here we have a volume of radiant matter insulated almost in a state of purity. Is there any evidence, then, that the Torricellian tube possesses a mind? We know that bad weather depresses our mind; it has the same effect upon the barometer, a phenomenon which philosophers have never yet explained. May not the phenomenon be an affection of mind in both cases? May not the Torricellian tube be very sentimental, but only labour under an inability to express itself, as is usually the case with such as are very sentimental. This may seem ridiculous, but that is no good reason why it may not be true, for ridicule is rather an evidence of ignorance than a test of truth; and were it not for the tables of the elasticity of vapour, the phenomena of light and radiant heat, in a word, all the actual phenomena, we might receive the doctrine, that a Torricellian vacuum may, for any thing we can affirm to the contrary, contain an individual sensitive and cogitative mind, notwithstanding the ridicule that some might be inclined to extend towards such a notion. For my own part, the opinion does not seem to me more ridiculous, than that the fixed stars should be made visible by hard particles striking off from them, travelling through space in right lines for years, and then impinging on the bottom of the eye; or even that the celestial spaces, though full of this matter of a vortex in the state of a chaos, should be regarded as a vacuum. Being thus impressed with a sense of the ridiculous in contemplating such notorious articles of modern philosophy, I must therefore be excused for refusing to reject an opinion, because it is ridiculous. All the phenomena of the Torricellian vacuum, however, are contradictory of the opinion that it has feeling or cogitation; it is therefore wholly to be abandoned. Are we, then, to suppose that nitrogen, the characteristic constituent of sentient beings, possesses a mind? Or is mind the result of a certain mixture of nitrogen, carbon, oxygen, hydrogen, and water? We cannot discover any reason why these substances should take on this phase rather than the diamond, manganese, chlorine, silica, or iron.

In fact, it must be acknowledged, that all known phenomena displayed by these and other substances, can be accounted for by a few simple laws of motion, the action of mind being excluded, and this is equivalent to the disproval of its action. If we suppose mind to be intrinsically an atomic phenomenon, we can discover no reason whatever why it should be found associated with nitrogen rather than other substances, which present no traces of mental phenomena. But if we assume that the body of an animal is a piece of mechanism contrived so as to serve the purposes of mind, an essence distinct from atoms, then there is a most obvious reason why nitrogen and no other substance should be the characteristic constituent of animals. For nitrogen is the only undecompounded form capable of going immediately towards the constitution of contractile fibres, by which an animal's body may be moved in obedience to its will.

It cannot be denied that the whole evidence which the first blush of this inquiry affords, is adverse to the opinion that sensibility and cogitation are essential properties of atoms in any circumstances whatever; and the most probable and satisfactory hypothesis is, that mind is a third essence, whose proper action consists in feeling and cogitation, and which, when associated with atomic bodies, directs the movements of subtile matter, as that subtile matter directs the movements of atomic matter. But this is a subject in which the mind is not satisfied with conjecture, or even with strong probability, while there remains a hope of acquiring certain knowledge.

OF THE NERVOUS SYSTEM.

It is agreed on all hands, that the part of an animal on which sensibility and perception are most immediately dependent, is the nervous system; and this is evidently the characteristic of the animal nature. Its development in the ovum is analogous to the development of an embryo in a seed during maturation. It assigns the place in the scale of organized beings, which the animal to be evolved shall occupy. It is that to which all the organs are subservient. The skull and spine give it immediate protection: the ribs render possible a regular respiration, on which the state of the brain is immediately dependent: the bones of the extremities give support to muscles designed to move the body according to the suggestions of the mind, which the nervous system accommodates or manifests. In a word, the nervous system is the superior of the animal machine, in relation to which all the other organs are developed and act. The muscular system, however, has obviously an organic structure and function far more perfect, and its development constitutes the climax of atomic action. By it the animal is enabled to assume its place in creation, and the organization of a muscle seems to be the most exquisite product of matter.

The structure of the nervous system, on the other hand, seems to be extremely rudimentary and merorganic, or almost crystalline. It is even more analogous to that of the bones, than the soft parts. It contains, according to Vauquelin, only 13·35 per cent. of animal matter, and that, of the more imperfect sorts, such as fatty matter, osmasome, and albumen; of the remainder, 80 per cent. is mere water, and 6·65 per cent. consists of phosphorus, sulphur, acids, and salts. It is not to be wondered, then, that nervous matter should be destitute of decided irritability, or the power of retraction on the application of a stimulus. What chiefly excites wonder is, that a mass, composed of such elements, should be capable of assuming an organic structure at all. The texture of the brain is so very delicate, or temporary, that cerebral matter cannot be frozen and thawed again, without complete decomposition. It putrefies sooner than any other part of the animal; nay, we may justly question whether the insensibility preceding death, be not the effect of a disorganization of the cerebral tissue.

The nervous system in the most perfect animals, consists of three parts—the brain in the head, nervous filaments diffused through all parts of the body, and foliaceous or capsular expansions at the tips of the nerves. The brain consists of two parts—animal globules arranged in particular directions, and a hyaline matter, which is aqueous or gelatinous, according to circumstances. The foliaceous expansions at the extremities of the nerves, are wholly composed of this hyaline matter. Could we, then, dissect away from a human body all the parts which do not immediately form a part of the nervous system, there would remain a hyaline filmy model of the human form; and were the parts permitted to fall away into more natural positions, without their organic connections being destroyed, the whole would possess the form of a plant inverted, the brain being the root, the vertebral column the stem, the nerves the branches and leaf-stalks, the hyaline expansions at their extremities the leaves. The *collum* or centre of the vegetative body, would be at the medulla oblongata, where the nerves of the respiratory system are attached to the symmetrical system. With regard to the atomic constitution of the brain, what chiefly demands our attention is the hyaline matter, to which the globular molecules seem evidently enough to serve as an osseous system, giving direction and support to the particles of which the hyaline matter consists. The quantity of this hyaline matter in man increases with the development of his faculties. It is more abundant in the human species than in any of the inferior animals; and it is remarked in dissections of the morbid brain, that dryness, or an increase of globular matter, is generally found associated with a deficiency of intellectual power. Every phenomenon connected with this substance, induces the belief that it is the sensorium of the animal, and that, upon its quantity and particular atomic structure, the animal's power of mind depends.

What, then, is the nature of this hyaline matter? In a recent brain it is found in a gelatinous or coagulated state: it disappears in water, and, by being congealed, is converted into water. "If a portion is cut off from a brain in a fresh state, before it has been put in water, and laid upon a dry plate of glass, and covered by a cup so as to prevent evaporation, a perfectly colourless aqueous vapour is exuded, which evaporates on exposure to the air, and hardly leaves any mark upon the glass. The cortical substance of the cerebrum contains also a fluid resembling the serum of the human blood; it has a yellower tint than the fluids in the medullary substance, or any other part of the brain; and when dry it assumes the glassy appearance, and forms the same cracks that serum does when dried on glass *."

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* See Sir E. Home's Lect. on Comp. Anat. vols. iii. and v. I do not doubt but Leeuwenhoek saw the complicated structure in the brain which

This substance evidently consists of water with some particles interspersed amongst it, which cause it to form a gelatinous mass. The gelatinizing agent is expelled by congelation, and departs spontaneously when the tremulous substance has, in the progress of decomposition, become simply of an aqueous consistence; for scarcely can a drop of water be found so pure, or an atmosphere in which it may evaporate so free from foreign particles suspended in it, but some stain will be left upon a plate of glass, from which a drop of water has evaporated. It appears also, that the yellowish matter taken from the cortical substance, and which was in a liquid state when examined, contains more of the gelatinizing agent than that taken from the medullary substance examined in the tremulous state, for it left, upon evaporation, a vitreous brittle substance, and not a slight stain only.

The physical characters of this gelatinous substance are every way the same as those of the gelatinous strata and masses, which we find investing as an atmosphere, or forming a nidus, or entering into the composition of many zoophytes and imperfectly understood organic forms. When they die, it wholly vanishes in water; and when even a large mass is suffered to dry, scarcely any thing remains unevaporated. I have often known a number of Planariæ, Polypi of Sertulariæ and Flustræ, and such creatures, when they happened to die, suddenly vanish, so that, after the course of a night, not a trace of them could be detected in the vessel of water, which the day before was enlivened with them. That the constituent gelatinous matter in these cases, as well as in the brain, is connected with the highest functions of organization, is also very evident. Ova are very generally enclosed in it. An Oscillatoria rooted in it may almost be seen growing. The vital activity of gelatinous animalcules, of small Beroes, and Medusæ, is quite wonderful. Nor is it less astonishing that the large medusæ,

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he describes, (Epis. Physiol. Epis. 34.); but that structure was evidently evolved by decomposition. The views given by Sir E. Home recommend themselves by their unpretending simplicity; nor is Mr Bauer a microscopic observer inferior to Leeuwenhoek.

which seem destitute of an apparatus for such a purpose, should be capable of symmetrical movements, and possess forms whose symmetry is most exquisite, though they consist of little else than gelatinised water.

The hyaline matter of the brain and retina, then, the expansions at the extremities of the nerves, the matter which constitutes a large part of the most highly animated zoophytes, and, in a less concentrated state, the humours of the eye and ovum,—these substances, and others that might be mentioned, seem all to consist of the same elements, possessing different structures according to the particular case considered. That this matter consists almost wholly of water, cannot be doubted. What, then, is the other element whose presence is indicated by the gelatinous consistency of the mass? The gelatinous condition intimates that the foreign ingredient in the water cannot crystallize, or that its particles are arranged in fibres rather than in molecules. Now spheroidal or merorganic molecules, silica, and alumina, are much more disposed to form hydrated fibres than to crystallize in water. But these cannot be present in the substance considered; for if so, they had been detected on analysis. Nitrogen and fixed air could not crystallize, and also form fibres; but they could not be retained in water in such quantities as to cause the gelatinous state, except under immense compression, in consequence of their mutual repulsion and tendency to assume the aëriform state. These substances excluded, and others disregarded to which stronger objections appear, it follows that we must seek for the gelatinizing agent in radiant matter itself; and, indeed, its disposition to form rays or fibres seems to enable it to give rise to the tremulous state more directly than any other substance. Moreover, all the positive evidence of the case is favourable to this supposition, and there is not even a conjecture that can be advanced against it. It could not be detected by the chemist, nor its presence otherwise discovered but by an inconsiderable loss of weight during the analysis of the substance operated upon; and this accords with the phenomena exhibited during its distillation from the plate of glass. It ought, like air, to be expelled by congelation or decomposition, and this was found to be the case. It ought to give a hyaline character or extreme limpidity, combined with a low refractive power; and this is conspicuous in all the substances now considered. It ought to be more immediately connected with phosphorescence than any other substance; and, accordingly, we find that most gelatinous animals are more or less phosphorescent, very many of them being visible even to our eye, which, being itself in a great measure composed of this matter, is capable of displaying a variety of phenomena which are phases of luminousness. Every circumstance in the physical characters of this substance, induces the belief that it consists of water penetrated by fibres of radiant matter. Its physiology satisfies the mind that there has been no misunderstanding of the physical evidence. For as radiant matter differs from all other substances, and is in many respects the most eminent, it is very reasonable to suppose that it should be found connected with functions quite different from all others, and in many respects the most eminent of all; and that such is the character of the phenomena of mind with which it is known to be most immediately connected, no one will dispute. But as this is a matter of no common interest, let us bestow a little more pains on the argument, by investigating the circumstances in which this hyaline matter is produced in the animal system; for, in reference to the zoophytic beings, it is evident that radiant matter and water are of all substances the most constantly at hand, if required, to constitute their bodies.

If the views advanced in the preceding pages respecting the structure of vital air and carbon be admitted, it mus also be granted that the use of respiration is, to charge the blood with pure radiant matter derived from the vital air of the atmosphere, and to abstract from the blood, in the state of carbon, feculent atomic or radiant matter, which has been altered in the quantity or condition of its subtile matter, by its existence in the animal system. This process is of all the most essential to animal life, and that on which every other function is dependent. Tracing the arterialized blood through the system, we observe that it takes two courses, one flowing over the mass of the body, the other seeking the head. The quantity of blood taking the systemic course, compared with that taking the course of the encephalon, is between 5 and 10 to 1; while the quantity of matter nourished by the systemic blood, compared with that spread over the pia mater, is between 50 and 60 to 1. Here, then, is a most remarkable supply of blood sent to the head. Tracing its distribution there, we find that it is ramified to an excessive degree of minuteness upon the surface, and among the plicæ of a membrane full of cells, on the inner aspect of which cerebral matter is found. The arteries, dipping among this cerebral matter, contain florid blood. The concomitant veins contain blood eminently dark. It is obvious that the same change goes on in the brain as in the lungs, with regard to radiant matter, but in an inverse order; that is, the arteries give out radiant matter to the brain; the veins withdraw feculent atoms. This function must follow from sympathy with the respiratory action, which is, as it were, the consecutive polarity. But it must also be aided by the triangular form of the columns of blood contained in the sinus; for, according to the principles of induction or imitation advocated in this work, nothing could be more effectual in disposing to the evolution of a radiant tissue than the presence of triangular columns, such as the sinus of the encephalon are. The analogy of the apparatus investing the *brain* with the lungs, or that investing the *air*, is most obvious. Nay, its structure is identically the same as that of the respiratory organ in reptiles, with this difference only, that cerebral matter, not air, occupies the pulmonary bags. Nay, more; the respiratory system in man is purely a repetition of the nervous system, and that to a great degree of minuteness. It is, in fact, the nervous system to the involuntary or nutritive department of the body, as the cerebral system is to the voluntary or muscular. Both are, indeed, united into one system, and are thus made to be mutually dependent. But it is only necessary to attend to the structure of both for a little, to discover that they are repetitions of each other.

The essential part of both the respiratory and cerebral apparatus, in relation to which the investing organs are formed, is a compound of which radiant matter is chiefly concerned in the animal functions. At the summit in both there is a mass, giving rise to a column which is ultimately ramified into an infinite number of branches, each terminating in an enlargement of the same matter. The aërial and cerebral masses at the summits of both, are severally invested by a system of peculiar cartilaginous plates, which, in the latter, ultimately contain earthy matter in their cells. The aërial and cerebral columns are, in both cases, contained in cartilaginous vertebrated canals; the cartilages, always in the latter, and in the most truly respiratory animals in the former also, containing earthy particles. The matter, in the ultimate ramifications, in both, is also continuously connected with that in the summit. Every thing is analogous. It would not only be possible to shew, with much detail, how exquisitely the larynx and its muscles (its function and position being kept in view) correspond in structure to the skull and its muscles; but it could be shewn that, by studying the organs in this way, we might ascertain the true nature of such an organ as that which has been called the Thyroid Gland.

The functions of the two systems, the respiratory and the cerebral, are also quite analogous. Cut through the *aërial* column, and the vital movements of the heart and blood are stopt. The nutritive and involuntary system is paralyzed, just as the voluntary or muscular system is paralyzed by cutting through the *cerebral* column. Change the aërial column, by substituting one, such as nitrous oxide, which contains a greater quantity of radiant matter,—the cerebral system is immediately charged with radiant matter, so that the individual is intoxicated. The sympathy between the larynx and the brain is indeed wonderful, as every one must have remarked, who has in any degree attended to the pathology of the mind. Were it necessary, this view might, in fact, be sustained by a host of evidence; but I will only mention farther, that, while in man, and the more perfect animals, which are both cogitative and instinctive, the respiratory system is a repetition of the cerebral; in other races, both are confluent into one. This is the case with insects.

"These exquisite little creatures indicate, by all their features, that they are most intimately connected with the radiant medium. Their organization is most admirable: their colours are most brilliant: their vivacity is extreme: their instincts are most wonderful: yet their nervous system is a very simple apparatus, apparently not superior to that of other animals, whose forms and vital powers are in every point quite inferior. But the nervous system of insects is merely a conducting tissue, to enable the different parts of their bodies to move with that symmetry and relationship to each other which the purposes of life demand. It is not that sensorium to which they owe their exquisite forms, their vivacity, and their wonderful instincts. The bodies of insects are penetrated symmetrically by an innumerable multitude of air-tubes, which are gradually attenuated towards their extremities, and ultimately become invisible. Before this, however, they have acquired opacity, a metallic lustre, the aspect and function of nerves. These tubes have been denominated Tracheæ, and their extreme parts are found to be constructed of spiral filaments, like the air-vessels of plants. It has been shewn, when treating of Carbon, that a spiral vessel may be so small as to transmit only radiant matter. There can be no doubt but these tracheæ of insects, towards their extremities, contain only radiant matter, air finding access only into those regions which are of considerable diameter. Hence we have in this beautiful arrangement the pulmonary and cerebral systems united into one. Nay, such are the organic functions of the conical tube, that, by such an arrangement, the same action is fulfilled as if there had been a muscular respiration. For it is impossible that a highly fluid body can remain in a conical tube without circulating during life. It must constantly tend to move from the region where it is in excess to that where it is deficient, so as to develope a symmetrical column. The radiant matter, then, having remained for a short time in the coloured extremities of the tracheæ, will tend to be pushed out by the pressure of the column in the region of greater diameter, and, forming itself into carbon, will unite with the surrounding oxygen. That this respiratory system performs the function of the cerebral, is proved by this, that, when any part of it is closed up, or cut off, the surrounding muscles are paralyzed, in the same manner as if nerves had been destroyed. These admirable little beings, then, are wholly sensorium, the perfection of their organization being adequate to enable them to gratify all their feelings. We cannot, however, suppose them to possess any power of cogitation, a process which seems to be conducted in the brain exclusively, and which is as distinct from feeling, as the fluttering of a bee's wings are from the act of sipping honey from the nectary of a flower. But of this more hereafter.

It remains, now, that we endeavour to detect the structure of the nerves. Each consists of a greater or smaller number of filaments lying parallel to each other. Each filament in particular, and also that fascis which constitutes the nerve, is, as usual, more dense on its external aspect, being invested with a membrane, as is the case with the filaments of the blood, chyle, muscles, the whole body; in a word, with every mass which is organized in a natural manner. Accompanying the nervous filaments, is abundance of blood, and of cellular substance. The constitution of the nervous filaments is evidently very different from that of any other filamentary substance in the animal system. They are not sensibly conical; but, on the other hand, each seems to possess the same diameter at its origin, and at its extremity. Hence the regular circulation of a fluid in them is almost impossible; for they are symmetrical already, and, in as far as they are concerned, there is nothing to determine a current one way more than another. They resemble the vessels of plants in their cylindrical character; and it is well known that, in these vessels, no fluid circulates, but that the sap pursues the course of the intercellular canals, which are quite deficient in symmetry, and therefore well fitted for entertaining currents one way or another. The nervous filaments are exceedingly minute. In a transverse section of a nervule, "qui pilo menti virilis crassitudine cedebat," Leeuwenhoek counted sixteen; and in another, about three times that diameter, he judged that there might be no fewer than 1000 *. The grossness of a nerve, then, depends on the number of nervous filaments, the quantity of blood and of cellular matter included within the skin or neurilema, and not upon a change in the diameter of the individual filaments. From one extremity to the other, from its tip till it is lost as a tractus in the brain, a nervous filament, provided it do not pass through a ganglion, appears to be a continuous cylinder, having the same character throughout. Ganglions seem to be justly regarded as regions for establishing sympathy, into which a number of nervous filaments, entering, while they still retain their own continuity with the sensorium, become capable, at the same time, of inducing a common state upon each other, and thus of enabling the parts to which they are distributed, to act in concert *.

But though there is every reason to believe that no fluid circulates along the axis of the nervous filaments, there can be no doubt but their substance is more rare in the centre than towards the circumference. This is asserted, not on the ground of observation, but of the nature of things. For though there are few observers more generally worthy of regard than Leeuwenhoek, who found the nerves to be hollow,

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* Epis. Physiol. Epis. 36.

yet it is evident that the hollows which he saw were the result of exposure and decomposition. They were large enough, he informs us, to suffer animalcules in the water to pass readily through them. Doubtless these animalcules derived the matter of their bodies from the very regions which were then seen to be without matter. Though such hollows, therefore, were seen, it would be very far from the truth to conclude that they exist in nervous filaments during life. That the substance of these filaments, along the axis, is, however, more attenuated than on the circumference, these microscopic observations, and the whole analogy of organic structures,—nay, even the atomic structures of the most perfect mineral bodies,—warrant us in concluding. Thus we have seen that the particles of iron, calcium, silicon, potassium, alumina, are hollow,—so also are the cylinders of the vegetable structure, the seed-vessels, the veins, arteries, and filamentary bodies of the animal system; hairs, quills, bones, and other parts, in which no fluid circulates, are also more rare towards the axis than the peripheral aspect. In a word, it is a law of motorial action, that similar molecules shall repel each other; thus an axis becomes a line of centres of repulsion. There can be no doubt, then, that the axis of a nervous filament consists of matter in a more rare state than that constituting the walls. It may, indeed, be said, that this has been observed; but observation, in such cases, can never be made, till the object to be examined has been destroyed by knives, and rude applications,—which, in relation to the axis of a nervous filament, must be as gross and unfit for dissecting it, as the tusks and trunk of an elephant would be for dissecting a straw.

All the circumstances of the case induce the belief that a nervous filament possesses such a structure as the following—that on the outside there is a membrane or sheath, on the inner walls of which are layers of globular molecules, with laminæ of water forming septa at regular intervals, each of these laminæ containing a senate molecule as its centre; and that the axis consists of a single ray of radiant matter extending continuously through the opening in the senate molecules of water, from the tip to the sensorium or summit of the filament. The nerves are evidently parts of the same individual organization as the brain, and must be composed of the same elements, viz. globular molecules, water, and radiant matter. The only question is, as to the details of their arrangement, and our only guides in this case must be a knowledge of their function, and of the structure of analogous organizations. With regard to the skin and globules on its inner walls, it may be said that these features are demonstrated. The only peculiarity in the structure now conjectured which requires proof, is the supposition of perforated septa at regular intervals along the course of the filament. That such is the case, is assumed from the fact, that all analogous structures in which there is not a rapid current, exhibit this mechanism. It is a structure in fact resulting, as will be afterwards shewn, from the laws of polarized action. It is observed in the filaments of venous blood and lymph, the fibres of the crystalline lens, the muscular fibre, the vertebral canal, the trachea, the sphincter muscles of the arteries, in all true zoophytic fibrils, and in all annulose animals. In the vegetable kingdom it appears every where, from the moniliform fungi and confervoideæ to the most perfect dicotyledones, so long as there is a single axis surmounted by a single organ.

Most perfect representations of this structure, on a large scale, are also seen in those organic remains, of a cylindrical or conical form, which are met with so abundantly among the more ancient strata, and consist of a series of annuli perforated in the centre, and united into a column; to which we may add the chambered univalves of modern seas. According to this view of the structure of nerves, it follows that the cutting of a nerve, however carefully its cut parts be applied to each other afterwards, must completely destroy its functions, and I do not know any phenomenon connected with the nervous apparatus of which it does not give a happy solution.

If this mechanism be granted to the nervous filament, or even that part only which assumes the existence of a single ray of radiant matter as the axis, it follows that two nervous filaments, if naturally in consecutive states of polarity (as parallel lines are always presumed to be), must execute functions the reciprocals of each other; and four parallel filaments must include a perfect ray of light, and constitute a nervule of the most perfect kind capable of a double function, the two parts of which are the reciprocals of each other. We have already found that every nervous filament extends between two cerebral masses, the brain and the hyaline expansion of cerebral matter diffused over the organ to which the nervous filament is distributed. If any one feels disposed to deny the existence of the latter, it comes to the same thing if he substitute the organ itself for the gelatinous hyaline matter diffused over it. Now it is very evident, that the most perfect nervules do perform two functions which are the reciprocals of each other—one, by an action in the nerve propagated towards the brain, announces to the mind the physical condition of the hyaline matter at the nervule's tip, which is an index of the state of the surrounding matter—the other, by an action in the nerve propagated from the brain, announces the mind's disposition to continue the extreme organs in their present positions, or to withdraw them, according as the state of sensibility previously announced, indicated that the organ was in a state of safety or not. It is evident, however, that a process of cogitation is not necessary to a removal of the organ to a position of safety, nor even a brain. For any violent action propagated along the one set of nervous filaments in one direction, must spontaneously induce a state of reciprocal action upon those which run parallel with them; that is, any acute pain felt or injury done to an organ must instantly, and independently of volition, give rise to muscular contraction.

For the accomplishment of this double function, however, in the most perfect manner, it is necessary that some mechanism shall be instituted by which the nervous filaments running parallel to each other shall be sustained in consecutive states. Let us see, then, whether there be any such mechanism displayed in the organization of such nerves as are known to possess most perfectly the double functions relating to sensation and motion. It is well known that we must, in this matter, direct our eye to the spinal nerves; and it is no less obvious that they display the very mechanism which we have anticipated. Each of these nerves is composed of two groups of filaments, having their origins from different crura of the spinal column; and that these crura are in consecutive states, appears from every phenomenon which they display. Nay, the very form of the roots, and the manner in which they spring out of the column compared with their partners on the other side, demonstrate that the nervous filaments derived from the posterior crura are positive in relation to those derived from the anterior crura. But the existence of such a state of things does not derive its evidence from this source alone: the introduction of the nerves of the respiratory system to establish a neutral plane, and the whole form and features of the cerebellum compared with the cerebrum, indicate the same. This I propose to illustrate afterwards; meantime, enough has been said to place it beyond controversy (provided the general principles of this work be admitted), that the substance to which the respiratory and nervous systems owe their peculiar characters, is radiant matter. That it is in all its features more fit than any other for being chosen as a sensorium is very obvious; but it has been shewn, that to suppose radiant atoms possessed of a mind as one of their physical qualities as matter, involves many grotesque and absurd notions, in addition to which it may be remarked, that metaphysicians speak of being able to prove the impossibility of mind having its origin out of that which consists of parts. And, certainly, without pretending to have confidence in a demonstration, whole axioms depend on the nature of something of which they pretend to be perfectly ignorant, and, under that warrant, at liberty to deny all assertions whatever respecting it,—without pretending to feel the force of such a demonstration, it may be asserted, that it is very incredible how mental identity could be maintained while the matter of our sensorium is changing as fast as the air in our lungs, unless the mind be some permanent essence reposing in that sensorium brought into action by its constant changes, and communicating through it with the material world.

OF MIND.

All that has been said, then, in the pages immediately preceding, respecting the structure of the nervous system, while it goes to shew that it is an apparatus better fitted than any other that we can conceive, for being the medium by which mind shall be united with a material world, goes also to increase the improbability that that sensorium is really the mind, and its movements the mind's actions. We have seen the strongest reason to suspect that mind is a third essence whose action is to feel and to cogitate, and which, through the medium of radiant matter, has power to give motions to gross bodies quite contrary to their natural motions, and such as are expressive of feeling or cogitation. But let us, then, prosecute our inquiry yet a little further.

Every man must admit that the existence of a feeling and cogitative essence, is just as possible as the existence of any other sort of essence or thing whatever.

But by what sort of evidence are we to obtain knowledge whether such an essence really exist or not? Belief in the existence of things is something of which we can say nothing more, than that it is a peculiar state of feeling awoke by sensations or certain perceptions, that are named truths. Every perception has a state of feeling proper to it, and when a perception awakes that feeling, wherein belief in the existence of the thing perceived consists, its reality is impressed upon the mind, and we can say no more about the matter. These beliefs may be awoke in various ways, and they possess various degrees of force. Thus, those feelings which are consequent upon the action of our senses, involve belief in the existence of things external to the mind. To controvert these constitutional testimonies, and affirm that they are not worthy of our confidence, is to refuse to acknowledge that we have the means of knowing any thing; for such beliefs are among the strongest of those instinctive feelings of which we speak; and all other beliefs, by the aid of which all processes of reasoning, and the evolution of knowledge, are conducted, are just so many other instinctive feelings arising intuitively in other given circumstances. The intuitive belief, however, consequent upon sensation, though very strong, yet is not the most forcible impression of truth that can be urged upon the mind. The belief in the existence of feeling and cogitation is yet stronger, and so is also the belief of an agent, of which these are the actions. The mistakes and imperfections of our senses, the manifest misrepresentations which they give of the movements of the heavenly bodies, and during dreams, make our minds familiar with such anxieties as, Do I really see; do I really hear? By these weaknesses, our reason doubtless is stimulated to inquire; but our universal confidence in the testimony of our organs of sense is moderated, the development of our beliefs being destroyed by collateral perceptions. With regard to the existence of feeling and cogitation, however, there is no place whatever for doubt; no room for reason. The belief demands no collateral circumstances for its evolution; a preceding state of the mind is enough; no high faculties are required; it is the memory of the moment; nothing comes between it and the object of regard. Our beliefs vary in intensity through a multitude of shades; but the most vivid, that which is most secure from the paralyzing influence of sophistry, that which is most truly the property of the mind, and of which we cannot conceive it to be divested in any circumstances of existence whatever, is the belief in its own cogitation. The next is, that a cogitating agent exists. But, between these two facts, there is the relationship which constitutes a process of reasoning. Both are indeed believed intuitively; but this is the case with every thing that is believed, and a process of reasoning is merely the evolution of some intuitive perception, such as "that cogitation exists."

Upon the testimony of the senses it has been uniformly assumed, in the preceding parts of this work, that an external atomic universe exists, which seems to me to be a truth so very strongly impressed upon the mind, that it is difficult to understand what those men mean, who differ in opinion as to this matter from the common sense of mankind. But is not the only difference between them and the vulgar, in their conceptions as to the mode of the world's existence? They do not think that there is less in the world than the others; but they have some transcendental conceptions as to the mode of the existence of things, which is certainly capable of being made very ridiculous, by those who find themselves competent to confute their own misconceptions of the opinions alluded to. Certainly, however, there is no reason assigned by philosophy, for altering the phraseology suggested by a common-sense view of external existence, and I feel very confident, and believe that my readers do so too, that an external material world exists in space; and that, if as good evidence can be brought forward for the existence of mind as an essence, distinct both from atomic and subtile matter, no one will demand more cogent proof.

The apparatus by which the mind acquires a knowledge of the substantiality of the world is our senses, which, being made of the same materials as the world, are capable of being acted upon by it, and the mind within persuaded, that the body investing it is not all that exists of body in the universe. From the whole tenor of the preceding work, it appears, that substances, to act upon each other, must be more or less similar in kind or quality. There is an universal reaction upon contact between all atomic matter, because all atoms are similar. When a gross body is struck or touched by another, they react upon each other. When our hand, which is a gross body, is brought in contact with another gross body, such as a table, there is a reaction between them. The hand cannot be moved, as if there were no table in the way; hence we say, that a solid impenetrable body exists in the way whither we move our hand. We owe our knowledge of the existence of the table to the fact, that our apparatus of touch is composed of the same sort of essence with the table. We find that the substance of which it consists is impenetrable, it being a law of the constitution of matter, that two atoms shall not occupy one and the same place; and that a cohering body cannot be moved without the application of force. But, in discovering that a table is solid or impenetrable to the hand, we do not, in point of fact, discover that there is more of existence or substantiality in it, than in the effluvia of a magnet, or in any other agent whatever. We only ascertain that it exists,—a discovery which we owe to the law of nature, that atoms cannot penetrate each other, so as to occupy the same place. To illustrate this, let us suppose the case changed (the sense of touch still being our guide), and that our hands were made of steel very strongly charged with magnetic polarity, and that two tables were in the way, whither our hands might be moved, one of them composed of magnetized steel, of similar polarity with our hands, the other a common table, the gross dimensions of both being the same; our magnetic fingers should now meet with a much greater breadth of resisting substance in the one table than the other, though the length, breadth, and thickness of the atomic parts of both are the same. There is now, over the surface of the steel table, a thick covering, of a hard elastic substance, for whose existence and substantiality we should have the very same evidence, if our organs of touch happened to be magnetic steel, as we have with our present fingers for the existence of those bodies commonly called hard and resisting. If, again, our organs of touch happened to be made of the subtile matter of magnetism, we could learn nothing as to the solidity of the table, but, on the other hand, would confidently affirm, that, if a table was any thing at all, it was some sort of subtile vapour opposing no sensible resistance, and capable of being passed through, as if it did not exist.

Without meaning, then, to underrate the testimony of the senses, it was necessary to say this much, to shew, that the substantial existence of mind, though such were, could not possibly be learned by the evidence of the senses, unless mind were matter. If mind be an essence distinct from that of which our nervous system consists, it can neither be seen, heard, touched, tasted, nor smelled; and, if we are to believe only in the substantial existence of such things as are borne out by sensible evidence, we necessarily exclude ourselves from the belief of mind as an essence distinct from matter. But the whole analogy of nature forbids us to circumscribe our belief in substantial things within the range of our senses. An ascaris has sensible evidence of the existence of nothing but that which it touches; an earth-worm of the existence of that only which it touches or smells; a mole of the existence of that which it touches, smells, or hears; a monkey of the existence of that which it touches, smells, hears, or sees. Because man happens to be liker a monkey than a mole, is he to believe that nothing exists of which he does not obtain sensible evidence? Because his fingers are made of flesh and blood, and not of magnetized steel, is he to affirm that the gross matter of a table is more truly a substantial thing than the effluvia of a magnet? It is only because our organs of sense are more similar to a table than to the magnetic fluid, that we think the former a more solid and substantial thing than the latter. To say, then, that mind cannot have a substantial existence, because it does not act upon our organs of sense, is merely to say that mind is not matter; and this is so far well, provided that, by matter, we mean that atomic and subtile body of which the sensible universe consists. But the notions respecting the nature of mind, as contrasted with matter, which are so generally current, and which are connected with misconceptions as to the nature of sensible things, are productive of much error. In fact, he who asserts the immateriality of mind, is commonly not contented with negative characters, till he has positively described the mind of a man as an infinitely minute *purum nihil*, owing its indestructibility to its substantial nonentity. Thus the spiritualist clears the way for the materialist, producing impressions in the latter quite contrary to his intentions. It is never to be forgotten, however, that, in investigating this matter philosophically, we must banish from our minds such notions as that colour and hardness are alone indications of substantial existence. A mind, though it may be passed through by our bodies, without occasioning the least resistance, or may itself traverse the diameter of the globe without meeting with any, may yet be as real a substance, and, for any thing that we can tell, may be, to some other substances, as hard and impenetrable as our bodies and the earth are to each other.

But how, it may be asked, are we, in the circumstances of this life, to obtain evidence of the existence of mind, as an essence distinct from matter? Its existence is indisputably proved where its action is discovered, provided matter do not exist at the same time. If this be done, we obtain all the evidence which it is possible to procure, of the existence of any thing whatever. Body is known to us only so far as its action is known, and what we call the qualities of bodies, are merely their modes of action in relation to our organs of sense. If the existence of cogitation and feeling be proved, where no matter exists simultaneously, the coexistence of a substantial cogitating agent is as clearly proved, and by evidence of exactly the same kind, as when we prove the existence of matter by laying our hand upon the table. The action displayed by the one is cogitation, by the other it is resistance; why the latter should be considered as more truly the characteristic of a substance than the former, there is no reason better than our ignorance, and the partiality of our views of the nature of things. It would be very absurd to affirm that, perhaps, the substance of mind is as dense and solid as gold; but it would be very untrue to affirm, that there might not be as much of substance in mind as in gold.

Those who have accustomed themselves to reflection, will perhaps think it needless for me to insist so much upon so certain a truth. But habits of reflection on such matters are, in our day, commonly stigmatized as fit only for the schools of the dark ages; and many physiologists content themselves with believing that mind cannot be substance, because really it must needs be so very rare and attenuated, that it could be nothing at all. The remarks which have been made, render it evident that it is absurd to conjecture as to the consistence of mind compared with that of matter, supposing that mind exists. But it also follows, that the substance of which mind consists is not altogether different from light, for it can act upon light, though it appears upon light only, and through the medium of the light under its influence can give action to atomic matter. If we do not admit this, we must admit Leibnitz' theory of pre-established harmony, which is very unfit for those who are parsimonious of faith, as those generally are who are inquisitive about such matters as are here discussed. The substance of mind, however, appears to be more dissimilar to that of light, than light is to gross matter, for both may be coexistent in the same place, and yet one of them may be in a state of action without necessarily exciting the other; while, on the other hand, so close is the relationship between light and gross matter, that the action of the one always involves the other in a corresponding action too. In presuming, then, that mind may be a third essence, we are to guard against supposing that the relationship of the three things, Mind, Light, and Atomic Matter, is a continual proportion.

But it is to a certain relationship of mind to matter, that we owe our evidence of its existence; for mind, in our present organic circumstances, by impressions of its action being stamped upon sensible bodies, is, in this way, brought within the range of our discovery. When we find matter thus impressed, an irresistible belief is awoke by the perception of the impression, that mind existed anteriorly to that impressed state of the body considered. When we see such things as astronomical and musical instruments, automatons, ships, and, sometimes at least, books, we are quite certain that cogitation existed prior to them, and consequently mind;

although, at the same time, nothing in these objects of art, *proves* that mind is different from a brain, or any other part of a man's body. The design displayed in such pieces of mechanism is the most satisfactory, and the best possible evidence of the prior existence of mind; for though we could conceive a sensible combination of atoms, having the aspect of a design, to be now and then produced intrinsically by the accidental movements of the mobile parts of an eternally changing universe of matter, we can positively deny that such things as those which have been mentioned could ever be produced by such an accident, because we know for certain, that, from the time of their origin to that of their decay, there are natural forces constantly operating to prevent their existence. The forms and structures of these instruments, and the forms and structures of all bodies demanded by the nature of things, are in opposition to each other. Call the nature of things accident, or what we will, it has been clearly proved that there are certain modes in which matter naturally moves, and not certain other modes; and when we find structures constituted by movements opposed to the former, we are sure that something else than the course of nature has made them; and if they display design, that which made them we must call a cogitative agent, whatever else we please to predicate regarding it. Moreover, by studying these objects in detail, we are able to discover more or less of the cogitative power of the agent who made them; and not only this, but, by considering their uses and action, we are able to discover the nature of the feelings which accompanied the cogitations; and thus we become able to affirm that such things must have been made by a human mind, or by a superior mind or minds, who knew the minds of men, and wished to instruct, to gratify, to enrich, or to mislead them.

Now, when we consider the structure of our bodies, as has been done by Paley, and every one who treats of their anatomy, whatever be his object, it is indisputable that they have been designed, and that a designing agent must have existed before them. This agent we may conceive either to be the mind within, or some designer without. We may conceive that the mind within is a substantial agent which had, from the beginning, faculties of a certain nature and number, whose reaction to aggregate matter around the mind does not become quiescent until all these faculties become vested with bodily organs. Thus we may suppose that the immediate artificer of the human body is the human mind, which, according to its intrinsic power and physical circumstances, becomes, in the course of years, invested with bodily organs as far as matter will serve it, more or less perfect, and in every case proportional to the energy or fulness of the mind which arranges or accumulates the particles around it by way of body. According to this view, the cause of our bodily organs being what they are, is the previous organization of the mind. The more immediate design is thus transferred from the body to the mind; but we are in no degree relieved from the necessity of finding an extrinsic designer. For the body, if it derive its origin in the manner now suggested, evidently results from the nature or constitution which the mind possesses, and not from any of its voluntary actions, all of which are in fact subsequent to the existence of the body, and cannot, in any sense, be its cause. The only difference between the two cases is, that the extrinsic designer is in the one supposed to have applied himself immediately to the body, in the other case to the mind. If we suppose the latter, instead of obscuring the necessity of an anterior designing agent, we only exalt our ideas of his wisdom from the feeling of elegance and fitness which such a mode of executing his design awakens. But this is taking for granted the essential existence of mind, the thing to be proved; it is therefore mentioned at present only incidentally, and with a view to shew, that, on neither supposition, can we escape from the necessity of a designer of ourselves. If it be said that had our bodies been otherwise than they are, our race must soon have ceased to exist in the physical circumstances in which they make their appearance, —that the body of a man is one of ten thousand things which happened to come into being, and, having in its composition parts that enable it to resist destruction, has survived, while all the others have speedily died as abortions, and that, therefore, the human body affords no demonstrative evidence of a designer possessing a personality distinct from what we call nature. I grant that there is force in this argument, and if we cannot prove that there is design extrinsic to the human body, it is *conceivable* that the human body is the result of accident as well as other things. If we grant that a stone may have lain on the ground from eternity, we cannot *prove* that the human body was designed by any thing else than the course of nature, the stone, and all other things around the body contributing to the execution of the design, each pulling off or adding, killing or causing to move, according to its physical character. But granting to this argument all the force which any one could contend for, it is only giving a different turn to the inquiry, not in any degree obliterating the evidence of design. It is prescribing a certain mode in which the design was executed, which excludes the pre-existence of a person distinct from the world, as the designer of a human being in particular. But still, a man is a no less admirable piece of mechanism; and if we suppose that such has been his origin, we are necessitated to animate the world, and grant that it has the power, though in an awkward way, of designing and executing most admirable contrivances. The possibility of the hypothesis now suggested, however, limits the demonstrative part of the common argument for final causes, to the proof of an *anima mundi*. There must be some power somewhat like human, but of far greater breadth, which makes things to be as they are; but whether this power be a mind, a cogitative essence which existed before the world, or whether it be a quality of the world, as we may *conceive* the mind of an animal to be a quality of its brain; these are difficulties which the argument, as commonly stated, does not clear away so as to prevent the possibility of supposing that the state of the matter may be different from what that argument contends for. That argument proves Deity; but it is nothing to our present purpose, whether we conclude, from the phenomena observed, that one mind has designed the whole, or that every region of nature has its especial deity. One of these two opinions may be shewn to be so highly probable, compared with the other, that it commands belief. But after all the philosophy which Plato, and the facts which Paley has brought to bear upon the subject, the demonstration of the existence of mind, apart from matter, still remains unaffected.

But how are we to discover the truth as to this matter? To shew that one of the two opinions in which the question is comprised is not true, because it is bad, is a very transcendental mode of proof, the logic of which would require great discussion; and it has this disadvantage besides, that such a mode of argumentation is not calculated to produce conviction, except in those whose minds are already established in the belief of all great truths, and not in those who are doubtful as to the very first principles of philosophy, such as the existence of mind as distinct from matter. The opinion alluded to can evidently neither be proved nor disproved, if we find design in certain sensible things only, and not in certain other things, —if we find the impress of mind only here and there among the higher combinations of matter. But it is clearly disproved, if we find that not only is matter, in its most complicated states, impressed with mind, but that, in its initial and primordial state too, it is so impressed by mind, that all subsequent evidences of its action are merely evolved impressions of that first seal.

To settle the matter in this way may be thought impossible, inasmuch as we cannot discover where matter, in its original state, is to be found, and examined so as to discover whether it embody design or no. But it is the fundamental principle on which this work is established, and on the assumption of which this argument is conducted, that the whole system of material things is made up of atoms every way similar, and duplicates of each other. It matters not, then, whether we affirm that the radiant medium, or water, or any gross body, is matter in its most ancient state, for all gross bodies, it has been shewn, are merely fissile congeries of radiant atoms; and to whichever hand we turn, in the belief that matter, in its most ancient state, is there, we find the same thing, viz. atoms of the same form and structure universally. Suppose, then, that, looking to one region, in which we find bodies expressive of design, we affirm that they were designed by the *anima* of another region of the material universe, to which we now turn; that second region, on examination, proves to consist of similar atoms, consequently we must seek a second designer for it; and thus we gain nothing in the argument by edging off from the acknowledgment that, if the atom displays design, a designer must have existed anterior to all atoms. For what is true of one is true of every atom, and the universe of matter consists of atoms only; we must therefore admit that a designing agent existed before the universe of atoms, and consequently that cogitation is not a function of atoms, but of some other essence having the power of making and of moving atoms.

Now, a perfect design consists of two parts,—a purpose, and mechanism by which that purpose shall be effected. The most noble design, in reference to matter, which we can conceive—but let it never be forgotten how ill informed we are, and how unable to conceive all the ends which matter may serve, or even to know whether those ends which we may conceive be among the greatest or the least—the most noble design in reference to matter conceivable by us is, 1. That it be made capable of becoming sensorial, that is, linked to mind, so that the latter may experience its phenomena; 2. That the phenomena experienced by the embodied mind be such as to awake agreeable feelings; 3. That these phenomena be not eternally continued, for then they must become repetitions of each other, which, continuing to distract the mind, as all material phenomena do, must nevertheless fail to please it. This last may seem an inconsiderable matter; but, if mind be progressive, as we find it is, and if it be capable of attaining a higher degree of intrinsic happiness, in consequence of the essential goodness of its sensibility, than any happiness which may flow from the observation or experience of material phenomena, then a state of rest in matter, or an abolition of phenomena, must greatly contribute to the excellence of the existing state of things. With regard to the fulfilment of the first of these conditions there is no doubt, since the host of animated material beings is immense. In this planet alone, there are probably more than a hundred thousand different species of animals capable of being seen by man, and the number of individuals in each species is usually inconceivably great. Moreover, we know of no reason whatever to induce the belief that other planets or stars are not equally teeming with sentient life. Flesh and blood is the apparatus suiting the purposes of our sensorium in the existing temperature of our world; but we know that sensorial matter exists everywhere; and how many different sorts of spheroidal molecules, besides flesh and blood, may exist in other regions, and be capable of serving the purposes of sensoria, we can nowise determine. Nay, no good reason can be advanced why flesh and blood themselves may not exist in other stars. It must be admitted, then, that most ample provision has been made in the designing of material things for uniting matter to mind.

With regard to the second particular involved in our conception of the best possible design, viz. that the action of matter should excite agreeable feelings in the embodied mind, there can be no more doubt than, in reference to the former, that it is fulfilled. Is not almost every material thing which we perceive beautiful? And is it not most pleasant to contemplate beauty? There can be no doubt that even a state of simple embodied existence is one of continued pleasurable feeling. Our very wants, the supplying of which only brings us to our right and most pleasant physical condition, have an agreeable pungency in them which makes us call them wishes.

It is only when our organization is in danger, and consequently our embodied existence threatened, that pain is felt, which, while it makes us more quick to the feeling of pleasure at other times, is of all conceivable expedients the most efficient for securing the mind's interest to maintain the entire state of its bodily organs. When a species has by some accident (not now to be inquired into) fallen into a state of disease, both in mind and body, as is too obviously the case with man, the exquisite structure of the mechanism of pain can scarcely be rightly perceived. But even in our present ignorance, by having regard to the whole of the animated creation, it could be shewn to the satisfaction of every one, and that to every degree of detail, that, by being embodied, mind is involved in a state of pleasant feeling, every departure from this state being only a piece of exquisite mechanism to secure the continuance of the organization, and consequently the state of pleasure in the mind. When a wound is mortal, insensibility usually accompanies it; and, if it be not mortal, yet such as unfits an animal for enjoying its existence, other individuals usually render it quite insensible, by appropriating it to themselves, and causing the molecules of which it consists to contribute to their own pleasant feelings. Nay, so universally does this provision of producing insensibility prevail, wherever there is a wound which unfits the animal for enjoying its existence, that even graminivorous animals often destroy the sensibility of their mutilated companions, though they make no use of their flesh. We who have the horror of death within us, and too many reasons for being alarmed at such an event, naturally regard such arrangements as those now noticed with a feeling of disapprobation, rather than the reverse. But the inferior animals have no consciousness of death. To be killed, while under pain, is only to be made insensible to the pain. If it be said that death, in all circumstances, ought to have been avoided; then this is granting that embodied existence is a state of pleasant feeling, which is the position contended for, or it is assuming that the animal killed cannot be replaced in creation, which latter we know is contrary to fact. Upon the whole, were it not that it would occupy space, and lead us aside from the main argument, it might be unequivocally shewn, that a state of sensorial existence is a state of pleasant feeling. This, then, the second idea of the best purpose conceivable by us, in reference to matter, is fulfilled. The third idea, that, in the course of time, intrinsic material action should come to rest, and motion be wholly obedient to mind, is also distinctly indicated in the ordination of the world. It has been shewn, in the preceding pages, that all atomic movements are the consequence of an universal tendency of atoms towards being included under a spherical form; and in reference to this form it has been shewn that it is incapable of intrinsic action, and that, if all atoms were spherical, and of equal magnitude, the material universe, except for insulated acts of mind, would be absolutely inert, and in repose.

It appears, then, that the tripartite purpose which matter actually serves is the best that we can conceive. It is made capable of being perceived by mind, in virtue of the institution of a sensorial mode of existence: this state of sensible perception is a state of pleasant feeling; and when mind shall have experienced such pleasant feelings long enough, and shall have acquired perceptions enough relating to the existing state of the material universe, matter may cease, from intrinsic action, and become wholly obedient to mind. But the reader will perceive that I am again taking for granted the existence of mind, the thing which remains to be proved. There is no harm, however, in doing so in such digressive parts of the argument as this, because the nonexistence of mind is not proved, nor made probable; and, therefore, as a thing that may be, we may treat of it where its existence explains phenomena. But though this be not granted, the argument stands untouched, and the disputant may neglect as much of what has now been said as to the purposes which matter serves, as he feels disposed. The body of the mechanism, whatever be its object, gives evidence of pre-existing mind, not to be disputed, though all other considerations whatever were excluded. Let us then consider, in a few words, the structure of the atom. The evidence of a pre-existing mind becomes more convincing, in proportion as the mechanism is perceived to be more peculiar and exquisite.

But what constitutes perception in a machine? Fitness, certainly, for all its peculiar actions, without superfluous parts. Every good engineer might be appealed to for confirmation of the statement that, when the pleasing of the eye is not to be considered, simplicity in mechanism, supposing the action not impaired by it, is the perfection of art; and that, when beauty of form must be considered too, something more than mere fitness is required.

In the preceding pages of this work, it is maintained and illustrated in a multitude of cases, that the mechanism by which all the physical and chemical phenomena of the material world are evolved, consists of an innumerable host of atoms, every way similar, and all of them duplicates of any one. This, then, is, of all mechanisms, the most simple conceivable; and that so grand and beautiful a system as the world is, should arise out of so simple elements, is itself an argument adequate to our purpose. But let us consider somewhat more in detail, the structure of an atom. This will at once serve the purpose of the present argument, and of a summary of views which otherwise are only to be found diffused over many pages.

An atom, then, is an exceedingly small body, consisting of two substances, viz. a hard nucleus, surrounded by a sphere of a very mobile, elastic, and rare nature, as the earth is by its atmosphere, or the sun and stars by their photospheres. This atom possesses two forms; one internal, developed at the confines of the nucleus with the subtile matter or light, that surrounds it; the other external, developed at the confines of the atmosphere of subtile matter with space. The internal form is the tetraedron, or the most acutely angular form possible. The external form is the sphere, or the least acutely angular form possible. Hence, according to the nature of matter, the structure of the atom is exquisitely calculated to dispose it for the evolution of a variety of spontaneous phenomena or movements greater than we can conceive by any other mechanism, as often as a number of atoms be placed in contact with each other: For it has been shewn to be a law in the nature of matter, that the spherical is that form to which alone rest is proper upon occasions where opportunity is afforded for portions of matter to bring their tendencies to remain at rest, or to move, into action. If both the external and internal form of the atom had been spherical, then atoms could have had no intrinsic tendency to move among each other. But because the internal form of the atom is composed of four plane faces, joined at four acute trihædral angles, the tendency of the atom, in virtue of this part of its structure, is to move; and yet it is so circumstanced that its movements cannot be productive of random combinations, which may or may not, according to accident, cause the groupe aggregating to approximate the spheroidal, and thus relieve it of its action. It results from the structure of its own external form, and from the circumstance that all the atoms of the radiant medium are duplicates of it, their spherical external forms being preserved entire, that all the movements originating in the angularity of the nucleus, must be directed towards the evolution of a spheroidal molecule, or a form of repose. The law of induction demands that the moving atoms group together, so that the aggregate possess the same form as that which prevails around, that is, the spheroidal, which is the external form of every atom of the radiant medium which fills the universe. This law of assimilation, induction, or imitation, has been so often illustrated in the preceding pages, and is so generally acknowledged by philosophers, that I need not insist at present on its illustration, more especially as it will soon demand our particular regard. The structure of the atom, then, its most acutely angular form towards the centre, and its spheroidal form, on its more extended regions, together with the fact that all atoms are duplicates, and that there is a vast quantity of atoms diffused through space, in a free and entire state, brings to pass, with wonderful simplicity of mechanism, and yet more efficiently than any other apparatus conceivable by us, that the universe of matter shall be in motion, and still all that motion be only a conatus towards a state of repose.

But though all this be evidently implied in the general contour of one atom, some further apparatus was evidently required which might be coeval with the era of intrinsic motion, and might serve to cause atoms to cohere when they have made an approximation towards the crisis of their action. Had the atom not been angular, it had not been under the necessity of moving, except in cases of mechanical impulse, and, in these circumstances, therefore, it had not needed any mechanism of cohesion. But since it was a part of the design of the material world, that it should move mechanically during a certain era, to which intent it was necessary to make the internal form of the atom angular, to these very angles do we find the mechanism of cohesion (rendered necessary by the atoms' tendency to motion) attached, so that when, by an abolition of angularity, the tendency to move shall be abolished, the apparatus of cohesion shall be obliterated along with it! Thus, without the institution of any new law, in reference to matter, or the contradiction of any now extant (which would amount to the creation of a new universe), an apparatus is contrived, by which the world of matter shall move intrinsically, and, it may be, contrary to the volitions of finite minds, during one epocha; while, during another, it shall be fitted only for rest, or for moving exclusively in obedience to mind.

That movement of an atom which constitutes fire is a conatus to obliterate the angularity of its internal form, and may also be explained on the principle of the law of induction; for when we consider the nature of matter, which is ever tending to expand to the utmost, we may conclude that the nucleus of an atom in a state of perfect coldness or stillness is in its most fully expanded state. That vibratory action of its angles, then, wherein heat consists, must only be so many partially successful attempts to reduce the tetraedron to a sphere. Now, in accordance with this view, we find that heat accelerates the movements of matter, that is, causes to be accomplished, in a shorter time, a certain approximation to the crisis of atomic action, which had otherwise required a longer time. Moreover, this acceleration is accompanied with a diminution of cohesive energy, which is another result from the mechanism of the atom, displaying the same exquisite power of contrivance, and intimating that, were angularity abolished, so also would be the power of intrinsic cohesion. Had there been no limit to the power of cohesion, atoms accidentally attached, might have cohered so pertinaciously that the completion of a spheroidal form might often have been prevented by their awkward appositions, and contiguous molecules might have been congealed in a mass rendered incapable of those insensible movements which, in the present admirable economy of the world, give rise to the most exquisite of all phenomena. By rendering the substance of the nucleus elastic, and by instituting that a decrease of attractive intensity in the subtile matter opposite the vibrating angles should accompany the action of their elasticity, all excessive cohesion is prevented; and, by imparting to the electric or repulsive principle the intensity lost by the gravitating or adhesive, the tendency to move into spheroidal positions is increased during the moments when it is, by the diminution of the restraining influence, permitted to act most freely.

We see, then, that, in the structure of the atom, there exists a mechanism, better calculated than any other that we can conceive, and most wonderfully simple, for enabling it to fulfil the grand purpose, first, of moving and displaying phenomena; and, secondly, of remaining at rest, or becoming wholly obedient to mind.

But it was stated, that, besides fitness for its function, such is the luxurious nature of mind, that, to be perfect, the mechanism of matter, so far as it is visible, must needs be beautiful also. It is true that the perception of fitness awakens an emotion very often not to be at once distinguished from that of the beautiful. There is, however, as will be afterwards shown, a very marked difference between these feelings; the pleasant feeling consequent on the perception of fitness, is an emotion resulting from cogitation, and therefore not immediately a sensitive phenomenon; while the feeling of beauty is an emotion starting up immediately on the beholding of a beautiful form, or the hearing a beautiful tone. The one is a phenomenon of reflection, the other is nothing but a particular sensation, more agreeable than other sensations of the same class. This subject will be illustrated afterwards; meantime it will be granted, that, besides fitness to perform its designed action, it was required, in the perfect element of things, that it should have some mechanism contrived in relation to the sensorium of embodied animals, or, what comes to the same thing, that the sensorium of animals should be contrived in relation to the element, so that the action of the one upon the other should, besides awaking the perception of the external object, bring the mind into that state of agreeable feeling, wherein the emotion of beauty consists. Now, this is accomplished in the most exquisite manner by the institution of polarity which constantly gives rise to symmetrical or beautiful forms, and not only to symmetrical forms, but to such combinations of symmetrical parts, that it is universally agreed that beauty, in works of art, is derived solely from a pure imitation of nature. There is, however, a certain element which comes in here, and incapacitates us for discussing the subject at present, viz. embodied expression of mind which awakens the feeling of mental beauty, or the reverse, and so modifies our feeling of formal or material beauty, when the object is viewed *en masse*, that it has generally been deemed impossible to discover the conditions of matter which develope the feeling of beauty; nay, even the illustrious Verulam stigmatizes those as triflers, who attempt to discover its elements. It will be afterwards shown, however, that the mechanism of polarity, by the symmetrical figures which it produces, is the cause of the evolution of such forms as we name beautiful. Now, this mechanism we find the possibility of evolving in every atom, for it is not necessary to assume, that polarity is any thing else than a consequence from the same state of things as has been supposed adequate to cause all atomic movements naturally excited be tendencies to the spheroidal.

In the preceding parts of this work, the evolution of spheroidal forms has been regarded as the effect of the action of a polarized structure. It has, in the preceding page, been traced to the law of induction, and ascribed to the fact, that the matter filling all the spaces around the congregating atoms, and in the celestial spaces generally, is composed of an innumerable host of spheres which dispose to the evolution of more. The intermediate stages of this evolution, then, must consist in the various states of polarity. The action of spheriferous induction makes one body of a certain form to be electro-negative, another of another form electro-positive; they unite because they are so, and this constitutes the details of the process, by which the influence of induction takes effect. We are not necessitated to complicate the mechanism of the atom, by assuming that a particular apparatus has been instituted, independently of the existing state of the surrounding medium, by which polarity shall be evolved. When we find that the subtile matter of atoms, which are grouped together into the form of oxygen, is intensely negative, while a little before investing the same atoms in the state of hydrogen it was intensely positive, we seem to be giving to subtile matter a latitude of function which is unsatisfactory; and, not being able to discover any reason why the state of the polarity of the subtile matter around an atomic nucleus should be changed by that nucleus considered by itself, nay, being rather averse to believe that the internal, temporary, or angular form, should have so great influence in modifying the external and more perfect form, the mind feels as if something here remained unexplained. But if we suppose that positive and negative polarities are conditions induced by the influence of the subtile matter surrounding the positive or negative form considered, then the mind is satisfied with the explanation, provided all the details of the phenomena of polarity countenance such a belief; because such a supposition is the simplest possible, and is in harmony with the analogy of nature. Upon returning to consult the figures and descriptions of electro-positive and electro-negative molecules, it will be admitted that the currents there described, and assigned as the cause of the phenomena, are just the phenomena which we should expect from the action of the law of induction or imitation now considered. But our knowledge of the actual mechanism of subtile matter in different states of polarity, is too imperfect to admit of a satisfactory discussion of any view of its origin.

As it is not, therefore, in any degree important to my present argument, I will waive its further consideration. All that would be gained, were it proved, would only be a simplification of the mechanism of the atom, and a reduction in the number of the laws of atomic action, that is of nature. Nay, there are some who think that a complicated state of things argues perfection of design, and, more especially, gives better evidence of design than a simpler state of things. Such persons, then, will deem that this attempt to simplify had as well be let alone. For my own part, while the actions and functions of any piece of mechanism remain the same in number and efficiency, I think that every part at first supposed to exist in the machine, because it seemed necessary to explain its action; and, by more detailed investigation, removed as a thing that does not exist, the remainder being still adequate to all the effects, is not decreasing evidence of design, but adding it, in the ratio that the machine is disburdened of superfluous parts.

Such, then, are some of the most considerable features of the atom, and surely, under any view that can be taken of it, it is the most wonderful and admirable piece of mechanism that can be conceived. That some Intelligence made this atom, is as certain a truth as any that philosophy or common sense can propose. Nay, not only does every point, and feature, and action which it possesses, bear the impress of supreme intelligence, but, like the instruments of art alluded to already, its parts are placed in opposition to each other, and all its activities are so many conatus to abolish this existing state of opposition. It is impossible, then, that one part of the atom could have designed and executed the other; for the action of either part is opposed to the production of the other. As Nature could not possibly make a ship, all its efforts being on the other hand to destroy such a production of human ingenuity; so neither could the one sort of matter in an atom shape and develope the other. The states of the two things are opposed to each other. The one possesses a tendency to destroy the other, and assimilate both. It is therefore impossible that the one could create the other. Since, then, the admirable mechanism of an atom cannot be the result of its own existence, and since all the matter of the universe consists of duplicate atoms, and nothing else, it follows of necessity that something else must have produced this congeries of duplicate atoms displaying such wonderful fitness for executing such noble purposes by such beautiful actions; and that this thing which produced the universe of atoms, must have had an essential or substantial existence at an epoch when an atomic universe did not exist. Now the action of this Essence consisted in acts of intelligence. Mind, therefore, is proved to be an essence distinct from atoms, anterior and superior to them; and as no one will contend, that, when the atomic universe was created, the creating Intelligence was destroyed either in his essence or personality, it follows that Mind is a third Essence. Of its intimate constitution we are, of course, unable to say any thing. But its characteristic is evidently to possess a focus of action essentially one and indivisible. In its substance it is certainly more similar to light than to atomic matter, but it is more dissimilar to light than light is to atomic matter. It is something purely *sui generis*, and, of all things in the universe, by far the most admirable.

Thus, the existence of mind, as a real being, and not a quality or action of other beings, is demonstrated as incontrovertibly as any proposition in philosophy whatever. The axioms are strong intuitions. The steps of the argument are very few, and their legitimate relationship is most obvious. The collateral hypotheses, by the use of which the disputant might strike out a by-path for himself, and avoid arriving at the conclusion now evolved, have been shown to be either untenable, or such as, after a circuit more or less fatiguing to the mind, invariably lead back into the broad avenue of the argument again. There is no possibility of a rational escape, and, happily, there is no reason to regret our confinement; for our argument has been no labyrinth leading to monstrous and destructive mysteries, to avoid which had been good for us, but to a temple displaying all that is most beautiful in the universe, in which every thing is inscribed by the Mind of a Supreme Intelligence, who now fills it with his living presence.

Of all the truths of philosophy, this doubtless is the most important: it may be the most awful; it must ever be the most august and the most animating. At such a discovery as this, that within us, which, as if urged by some father-seeking curiosity, may have been, long years, impatient of all but research into the nature of things, ever feeling that lamps expired too soon, and eyelids became too soon languid, discovers a heavenly expanse of glorious truths above it, and feels them showering down upon its parching wishes.

It does not belong to us here to enlarge upon the attributes of the Supreme Intelligence, which may be deduced from a survey of creation. The design of the universe indicates that He is supreme in goodness: He is therefore supreme in happiness, for happiness is in feeling what goodness is in essence. The mechanism by which the design of the material creation is worked out, shews also that He is infinite in power and knowledge, which renders Him infinitely able to diffuse to any extent the happiness, which, independently of all other things, intrinsically belongs to Himself. But in attempting to conceive, by the light of reason, the fulness and glory of Him, to whose every attribute we append the term infinite, we feel that we are labouring in vain; and, in measuring the Divine mind by the compass of our own, are, in fact, only attempting to make our own divine.

But there is especially one attribute of the Supreme Being, which the naturalist must never forget, and that is His omnipresence,—a truth which is never disputed by any one who believes in the existence of the Creator of the Universe. On this all-interesting subject Newton has the following remarks*, and others of a similar import are found in a contiguous page of his work. After describing the indications of design every where apparent in creation, he continues thus: "And the instincts of brutes and insects can be the effect of nothing else than the wisdom and skill of a powerful ever-living Agent, who, being in all places, is more able, by his will, to move the bodies within his boundless uniform sensorium, and thereby to form and reform the parts of the universe, than we are by our will to move the parts of our own bodies. And yet we are not to consider the world as the body of God, or the several parts thereof as the parts of God. He is an uniform Being, void of organs, members, or parts, and they are his creatures subordinate to him, and subservient to his will." This truth of the Divine Omnipresence is too often forgotten, even by those naturalists who believe it as a matter of sound opinion; and yet, surely, so long as so great a fact in the existing constitution of things remains unheeded, we cannot expect to come to any true knowledge of the causes of the more sublime phenomena of nature. When we are attempting to investigate the phenomena displayed by an animal, for instance, we consider it in relation to its own organs, the air, the water, the place where it dwells, &c.; but is there any likelihood of our coming to a true perception of its nature, so long as we neglect to view it in relation to the greatest of all possible influences, the most powerful of all agents, the Supreme Spirit, who pervades every place? It is certain that the presence of the Divine Mind must either produce some effect upon such a piece of material mechanism as the body of an animal, or it must not. We have seen that the mechanism of an animal does not constitute an animal, but only an automaton; while it is certain that the sensoria of animals are the seats of feeling, and many of them of cogitation too. Are we to suppose, then, that every animal species is animated by an individual mind? Or, rather, that the individuality and peculiarities of the animal's sensibility and modes of cogitation depend upon the structure of its sensorium, that is upon its organization, while its animation is immediately due to the presence of the Supreme Intelligence, in whom it lives, and moves, and has its being,—the law ordained as to animation being this, that every entire group of molecules naturally constituted, and provided with an internal tissue of light or radiant matter, should become sentient, being supplied with a degree of individual sensibility, suited to its capacity for gratifying its desires, from the great Source of life, who, thus dwelling in light, creates myriads of specks of derivative animation, each for a time delighting in its being, then vanishing, according to the laws of atomic movement, to be succeeded by another and another like itself?

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* Newton's Optics, Q. 23.

This opinion would explain why animal forms should be, as we find they are, constantly tending towards a more perfect organic development; for were they animated in this way, we can only believe that the organizing influence which actuates them, must be constantly tending to raise them in the scale of beings, as far as the physical circumstances around them admit. Why they should possess the forms and instincts which they do possess, and not others, will appear by-and-by, after we have bestowed some pains on the consideration of Man. But what shall we say of this strange Being? It is evident that He is not animated in this way. His moral and natural history, every circumstance respecting man, single him out from among all animals as a peculiar species, and prove him to be either a microcosm, or else a mystery. Now, it is to be remarked, of all the proceedings of the Supreme Being relating to the present universe, that nothing is done of a sudden and in full development at once; that something new is never violently attached to some other thing quite different from it. Every thing is brought to pass by gentle transitions from one state to another, after the manner of ordinary evolutions. The calm ocean is not on a sudden raised into a storm, at the moment when the wind rises. The brightness of day is not suddenly followed by the blackness of midnight. Mountains do not suddenly rise from the level plain. The heat of summer is not suddenly followed by the cold of winter. An infant does not suddenly start up into manhood. Every thing is accomplished perfectly, yet always in the fulness of time, and through a series of stages of successive evolution. The mode, then, in which we have conceived that the inferior animals are animated, may be regarded as one step in the evolution of particular intelligence united to matter. They have not permanent individuality, nor have they an intrinsic power of acting contrary to the Divine will, with the consciousness that they are something which can do so if they please. They are only capable of individual sensibility and cogitation, so far as their sensorium can accommodate mind. So far of the first step in the creation of finite intelligences, in connexion with gross bodies; the second, according to this view, we should infer to be man. That his sensorium is the *locus* of a sensitive and cogitative substance present there, no one can doubt; and that this mind is peculiarly his own, there is too much reason to believe; not too much, assuredly, in relation to the thing to be proved, but too much in relation to its quality, and the nature of the facts in which the evidence consists. For one of the strongest arguments for the persistent and proper individuality of the thinking and feeling principle of man, is his capacity to act maliciously, his ability to act in a manner contrary to that known to be alone consistent with the activities of the Divine Mind. Had man not been capable of crime, it would have been more difficult to shew that his sensorium is animated in a manner different from that of the inferior animals; for, though very strong probabilities could be advanced for such a hypothesis, yet the manner in which it has been presumed that the sensoria of the inferior animals are animated, seems adequate to account for every efficiency of cogitative power which he may possess, but it restricts sensibilities and moral dispositions to modes of a certain range only. The manner in which this specific and permanent mind is multiplied by generation, may be considered as illustrated by the phenomenon constituting what I have supposed might be a subordinate era of the creation of finite intelligence. The animation of the sensorium of the fœtus by the parent, may be regarded as a repetition of that law, by which it was decreed that the sensoria of such beings as have not specific minds intrinsically peculiar and proper to them, should be animated by the Supreme Mind universally present. Such phenomena, in which a *subordinate* function or apparatus in a *superior* animal, is merely a repetition of a *primary* function or apparatus in an *inferior* one, are of constant occurrence in physiology; and let it never be forgotten that the analogy of nature is to be observed.

If we grant the essential existence of mind at all, no one certainly will be disposed to believe that there are no more minds than one in the universe; and no one, on this supposition, will be disposed to deny the specific and permanent individuality of the human mind. I say permanent individuality; for it is an obvious consequence of the admission that we have a specific cogitative substance present in our sensorium, different from all other cogitative substances, that it must *naturally* continue in existence, notwithstanding that separation of our bodily molecules wherein death consists. For, even admitting, what some may be disposed to contend for, that it is impossible to conceive how a human mind could exist without a vehicilum or sensorium, such as that to which it is primarily attached, and in its nature made suitable to; even granting this, not the slightest difficulty in conceiving disembodied existence ensues: for it is evident that the celestial spaces are filled with matter the very same in form and substance as the sensorium, wherein the embodied mind is now lodged. Finding, then, that the universe of matter consists of a multitude of individual bodies, it is reasonable to believe that the universe of mind does so too.

The human mind, as is evident from every phenomenon, holds a most peculiar place in the scale of created intelligences. With regard to the ratio of its power, compared with that of its sensorium to accommodate it, we may observe, that it is left more free than those of the inferior animals. It is not so perfectly supplied with sensorium as they are, that by such an arrangement, and the experience of occasional sensorial discomfort resulting, it may be made to wish, and disposed to look for, another mode of existence. The perfection of the sentient principle by which the sensoria of the inferior animals are animated, led us to anticipate that gradual improvement in organization in the animal kingdom which most naturalists contend for. The incapacity of the human sensorium, and of our organization in every feature, to express and truly accommodate our mind, is very remarkable. Who does not feel that he has within him the possibility of discovering a far greater breadth of truth, and of experiencing intellectual emotions, far more strongly than his corporeal wants and desires, and his organic and personal confinements permit? Who does not experience that all organic inventions, even language, the noblest, is an apparatus whose application to feeling, causes the latter to shrink upon itself as from an amputating instrument? The very intellectual consideration of an emotion which must be exercised before words can be applied to it, hungers it to death, and to make out its description is to undertake its funeral. But if language cannot rival feeling, gesture cannot; and though both together be more efficient than either by itself, yet who, in witnessing such expression of feeling, does not find that his mind is careering on before the tragedy, and that the best acting is after all only playing, only an imperfect imitation of that which the mind has already represented on some internal stage, in a manner so much better suited to the mind's perceptions of the subject, that the best player is felt to be little better, in as far as expression of the subject is concerned, than one of those soldiers who are put in front of a regiment to make certain extravagant movements bearing a certain relationship to the evolutions of the armed companies, but wanting all the point and force of the moving bayonets? And if another cannot, by the use of his whole faculties and organization, express to us so much as we already feel who have conceived the plot, no more do we find our internal organization able to accommodate itself to all that we know our minds to have the possibility of feeling. Ignorance has drawn a dismal circle around us, concentric with which, and too near the centre, lies the fairy ring of blessed intuition, from which here and there rays of truth do indeed shoot out towards the region of the unknown; but a crowd of most heterogeneous things, entrapped by sensation and retained within the mind by martial law, drink up and destroy the streams of truth, and force the mind's current into the channels of error. Nay, so inadequate are our present organic circumstances for accommodating the mind in all its activities, that our strongest and most vivid states of mental action operate like a freezing mixture on the body, and its expression is never so fit to tell the mind's grandeur as when it seems to stand like living marble. Under stronger emotion the whole organic mass becomes an involuntary, convulsive, or tremulous thing. Every strong state of feeling causes some organic disturbance in our body, wisely designed to remind us of the necessity of acting cautiously so long as we are under the necessity of seeking our way through existence by the use of reason, and to temper our sensibilities lest they stretch beyond our organization's ability to bear, and give rise to derangement, sickness, or death. But that serious accidents should not occur to the brain on slight occasions, our all-wise Creator has, as it were, directed the too vigorous reaction of the mind during emotion chiefly upon the blood, which is at once able to bear the agitation, and, in virtue of its inherent tendency to a certain rate of movement, act as a *governor* and check upon the excessive mental action.

Assuming the existence of mind as an essence distinct from body, all this is satisfactorily explained. On assuming that mind is merely a function of atoms, these phenomena, and the whole study of physiology, are reduced to a chaos, and ourselves to creeping things, without either history or destiny. We cannot, indeed, under any hypothesis, explain all things. Unless we could "carry the torch of discovery around the universe," and were admitted to the counsels of the Eternal, we never could tell why the things that are, exist, rather than some other things that might have been. Certainly there was no necessity to make it impossible for other things to be, if the Omnipotent had so willed. But it is all beyond the province of human science to prognosticate the contingencies of Omnipotence and Eternity. It is our province only to inquire into the nature of the things which exist; and our inquiry here is hallowed by the Creator, only when our discoveries awaken emotions of intellectual happiness. Such happiness can only arise from the perception of goodness; and so often as our researches lead us to the perception of goodness as their legitimate conclusion, they lead us to the source of things. It is this perception, and this only, which makes the philosopher, the man who has the disposition to live like a god. It is this which wipes away the scales of that lizard armour in which, while in ignorance of the nature of things, we enclose our small spirits under the name of a necessary selfishness. Ceasing to be afraid of others' badness, when our own is subdued, our selfishness consists only in seeking to diffuse to others the happiness which we possess. We leave to the wicked, without occupying ourselves in small disquietudes and in self-degradation, to take from us whatever they find themselves able and disposed to do, assured, that by affording us self-touching exhibitions of ignoble conduct, they strengthen our hatred of it; and that by giving us opportunities of exercising forgiveness, they improve our hearts.

But let us enter more minutely into the structure of our mental constitution.

OF THE PHYSIOLOGY OF THE HUMAN MIND.

What is the nature of the mind's action? At what crisis is it aiming? What are its laws, and why are they what we find them? It has been ordered, that, in our present organic circumstances, matter is to afford us the subject of almost all our positive knowledge. We have seen that to its mechanism we owe our demonstration of the existence and attributes of the Supreme Being. May it not be, that the laws of material actions are merely embodied repetitions of those by which mind acts, by the knowledge of which it is provided, that we may acquire a knowledge of what we are, how we act, and what we tend to? For, as reflection on our own successive mental states implies a particular and unnatural occupation of the thing studied, we cannot, by reflection and consciousness alone, detect the causes and object of those successive phases which the mind assumes during the currency of life. This process is analogous to those experiments of physiologists in which the observer wounds or mutilates a vital organ, and having thus brought the animal into a state of diseased action, concludes respecting the cause of its natural actions. By such means, much may be learned, but only so much as to enable us to compare the successive phenomena of mind with other things, and observe their agreement or disagreement. It is only by the possession of a physical exemplar of the action of mind, conceived of by sensible phenomena, that we can ever hope to learn the reason why the mind's action is what we find it, and not otherwise, or, as we might say, the structure which necessitates it to act as it does, and the object of all its unceasing activities. That such a sensible exemplar is not impossible, the common language of mankind assures us. For we speak of our mind being moved, expanded, elevated, depressed, acute, rigid, soft, &c.; these, and all our natural qualifications of mind, being in fact borrowed from some felt similarity between the action of matter and of mind. Nothing can be urged by reason or philosophy against the hypothesis, that the visible universe is a model of the invisible; and that, from the observed laws and tendencies of the former, the laws and tendencies of the latter may be learned. It has been shown, that the atomic universe is posterior in point of origin, and inferior in point of nature, to mind. The wonderful simplicity, harmony, and parallelism, which we find in all other things, favour the idea now suggested, and there is no reason why we should not inquire if it be so. Moreover, if it be found, that, by the application to mind of those laws and tendencies by which it has been maintained that the action of matter is governed, we are able to explain the laws and tendencies of mind, a very strong argument is established that I am right as to both. For it is incredible that two such things, unless both were true, should agree with each other.

According to the views which have been unfolded in the preceding parts of this work, the modes of the action of matter, which consist in movements developing forms, a new kind of motion being proper to each, are occasioned by three influences, and consist in imitations of three things.

1. The nascent or active substance, in every successive moment of its existence, imitates itself as it existed in a preceding moment.

2. It imitates or tends to assume the forms and actions of surrounding bodies.

3. It imitates or tends to assume the form of the sphere, the most perfect and universal form.

In consequence of the first of these influences, specific character is maintained through the whole of its existence. When the second or third prevail over the first, its individuality is destroyed. This specific imitation may be exemplified by the instance of the development of a crystal. Wherever a molecule is deposited, immediately afterwards another is deposited, as an image of the first, according to the laws of polarity, that is, not in a parallel, but in an inverse or symmetrical position. Were molecules thus to be deposited in two series, the second series consisting of images or imitations of the first, the first being determined to their positions as images or imitations of those which were aggregated before, without any collateral influences, then the growth of a crystal would consist merely of layer after layer around the nucleus which was the focus of aggregation. There would be no such thing as fundamental and secondary forms, no true evolution. The growth of a crystalline or other individual would only consist in an enlargement of the fundamental form or embryo. But the nascent form, while imitating its own prior states, is, from the universal prevalence of the sphere around it, also constrained to imitate or tend towards the spheroidal form, which it is enabled to do by the institution of equatorial and polar states in its subtile matter, or what may be called Spheropherous polarity. Hence its growth consists of a real evolution, in which its pre-existing form is never completely repeated in any successive period of its growth, but only so much of it as preserves its individuality or specific sameness. Were the molecules successively aggregating to form a nucleus, influenced by nothing else but a determination to assume positions which might continue the identity of the individual, a simple solid, or one composed of homogeneous molecules and of sensible magnitude, never could be produced. During its increment, it could only be extended in length or in breadth, or in both, but not in three dimensions, length, breadth, and thickness at the same time. Hence masses in which the specific character is most strongly determined, and whose growth is determined chiefly by self-imitation, must tend to be composed of a heterogeneous tissue of fibres and laminæ. The spheropherous influence acting on aggregating molecules, is like a compressing force bending round fibres into circles, folding up laminæ into parallelopipeds, and covering every plain face with a pyramid. It is this which gives strength, duration, and unity to the nascent or active body.

But, besides these two influences, there is a third to which this body is subject, and that is, to imitate surrounding ones. By this a social and harmonious aspect is given to a group that have grown up together. The form of a crystal receives a modification from the rock out of which it grows. Every natural object is always found in keeping with the other objects and conditions of physical existence around it, and the mechanism by which such a state of things shall be sustained can often be traced. Thus, on a meagre meadow the herds soon become meagre too, or imitate the state of the meadow, and the mechanism by which this law is fulfilled, is obviously that of the assimilating and excretory function continuing to operate under a deficient supply of crude matter received into the system. This is mentioned merely to show that we are not to regard the phenomenon of imitation as more mysterious than others, but that, like others, it is accomplished sometimes by an apparatus which we can trace, sometimes without any intervening mechanism to be discovered by us. Thus it may be said that the continuous identity and specific character of an individual depends on actions which are self-imitations repeated in successive moments of increment; its social character on actions which are imitations of surrounding individuals; and its ultimate character upon actions which are imitations of a perfect species which is universally present.

Is this, then, a *visible* exemplar by which we may learn the nature of our mind's laws and tendencies, and the structure of things which are *invisible*, and therefore unfit for being perched upon at once as objects of knowledge?

In the existence of a perfect, supreme, universal, and immutable Mind, and of active, changing, subordinate minds, we have all the elements necessary for rendering the investigation reasonable, Nay, the very statement of the bare elements of the two classes of phenomena, starts at once a very obvious similarity. Further, that there is such a thing as imitation, both conscious and unconscious, among animated beings, is most notorious. Therefore, *prima facie*, there is nothing whatever opposed to the investigation; but, on the other hand, every thing is favourable. It will be observed that I use the word *imitation* merely to express the act of repeating a state or mode of existence more or less perfectly, which has been previously developed in the individual's self or in some other individual. There may, on the part of one animal, be a great deal of imitation of some other animal, without the former setting about the imitation with a conscious wish to imitate, or acquiring any knowledge whatever, when the act of imitation is over, that it has been occupied in imitating.

The knowledge that we are imitating is almost always veiled from us, often by most beautiful devices, as will afterwards appear when speaking of Beauty, but the action is not the less on that account a true act of imitation. The extent to which mutual imitation takes place, even while there exists at the same time a strong specific character in every individual, and most generally a strong wish to avoid imitation, is beautifully seen by the traveller who crosses a number of natural frontiers in a short time. Each group of men and women which constitute a community are, in their modes of action, and very much also in their personal appearance, characterized by a general sameness, arising from a general imitation. In one quarter we find the most ridiculous practices and gestures gone about by every one as matters of course, as to the history and meaning of which, any individual interrogated knows no more than that it is a habit among the people of which he is one; and any one who proposes to act reasonably and avoid following the general imitation, has an unpleasant feeling, not only in being thought singular, but in being singular. Man has not individuality and intelligence enough in a state of society to subdue the apishness of his sensorium, as one may sometimes see a listless monkey lying snugly in an agreeable warmth, when in a manner drowsing in comfort, yet with its mind a little active, imitating the movements of our hands, arms, and feet, if not involuntarily, at least without a wish or an effort of attention; so men do constantly and involuntarily imitate each other, not in yawning and other muscular movements of the respiratory system only, but in movements of the voluntary parts. Sympathy is a name by which some suppose that they express the cause of this phenomenon; but it is chiefly the phenomenon itself, the imitation accomplished or attempted, to which our argument now relates. A volume might be written on this subject; but enough has been said to shew that Imitation does exist as an inherent tendency in our nature, and the nature of animals more or less similarly constituted. Let us endeavour to discover whether the phenomena of mental action be not invariable imitations, conducted under three influences exemplified in those by which atomic action is conducted.

Mental action is indeed very different from atomic action, yet not so absolutely incommensurable that the mind is unable to discover any relationship or parallelism between the several phenomena of the two classes. In fact, though it is inconceivable that cogitation can be an act in which any thing changes place or moves, yet the successiveness of the different parts in a process of cogitation, institutes a resemblance between it and motion, strong enough to be felt by the mind. The new form and volume of mind, as it were, which we possess in the moment during which we exist under emotion, makes us feel it not absurd to compare an emotion to an expansion or shrinking without locomotion; while the different emotions might be conceived to bear to each other an analogy somewhat like that which different forms do to each other. I do not say that it is not absurd to conceive an *analogy* between the two classes of phenomena, those of mind and of atomic bodies; but only that it is not absurd to conceive a certain resemblance or parallelism in the two classes of things, each individual in each class having to the succeeding one the same analogy. There is strictly no analogy between the two classes, but only a resemblance arising from the corresponding phases of two analogies.

Were I, according to the *beau ideal* of Linné* (not to use more than twelve words in characterizing any species), to attempt to comprise the most eminent features of mind within so small a compass, I would say that—mind is a sensitive and perceiving change-seeking essence, happy in the changing, and uneasy when change is prevented.—*Sensibility* is, as it were, the vital principle or cause of the mind's activity. Every state of sensibility has a certain change, either corporeal or mental, as its sequence, by the accomplishment of which that state of sensibility is transformed, and a new state is developed, having a new change proper to it. When the change proper to any state of sensibility is prevented, the mind is detected to be in a state of dissatisfaction or uneasiness. This discovery is made by *consciousness*, or the mind's power of knowing its own states, a perception, which is confined to minds only of the superior orders, whose own preceding states are thus viewed by the mind in the present moment of its existence in the place of external objects. Minds of more limited compass are capable of perceiving such objects only as are truly external to them, and not themselves in pre-existing states. Without denying any thing that Æsop meant to teach, perhaps it might be maintained, that if all animals had speech, only a very few terrestrial species would think of inventing a pronoun of the first person. The song of a lark or a nightingale is as fully expressive of the sensibilities and perceptions existing in its mind during its song, as the language of a man is of his mind during the time he speaks. The state of sensorial or corporeal activity sought, viz. the song, issuing immediately out of the internal song-seeking state of sensibility existing in the bird at that moment, prevents other subordinate, collateral, and aberrant states of mental activity, including perceptions suggested from within, consciousness, and all sorts of knowledge whatever. All those states of mental action which either constitute cogitation or the materials of cogitation, are merely interludes between the acts, taking place while a curtain has fallen between some state of sensibility and the physical change which is its natural sequence. The various perceptions which are in man, in these circumstances, apt to strike up a collateral and simultaneous origin, are, as it were, the different instruments in the orchestra, each having a march of its own, according to the same general laws of harmony; yet many of them, taken by themselves, making sad and absurd music, and destroying the composition as often as they are suffered to depart from their several places of just relationship and subordination.

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* There is less occasion for ridiculing this fancy of Linné, than there is for lamenting that so much of the Philosophia Botanica is neglected by many modern methodists. Nay, the admirable remarks which accompany the passage alluded to, do more than atone for the conceit of fixing upon a given number of words for a specific character. "Pulchritudo artis brevitatem exposcit, nam quo simplicius eo etiam et melius, et stultum est facere per plura quod fieri potest per pauciora; Natura etiam ipsa compendiosissima est in omni sua actione."—*Phil. Bot.* p. 228.

These remarks are enough to render obvious the distinction often made between two modes of action ascribed to mind, the instinctive and cogitative or rational. The instinctive action of mind consists in states of sensibility followed hard by their proper change or changes in the animal's external circumstances. The cogitative action of mind consists in states of sensibility followed, not by voluntary movements, but by perceptions or ideas giving rise to new states of sensibility of different qualities, some of them preferable to others; and reason consists in selecting and preferring those which are felt to be best, or apply themselves most cordially to the nature of things. One perception preferred awakes the new perception which is its sequence, and thus the train of perceptions goes on till some one is developed of a nature calculated to give rise not to another, but to a voluntary movement. Each perception or idea has indeed a peculiar state of sensibility as its substratum, which, as well as the perception itself, may, in many cases, become an object of the mind's consideration. But it always happens, sooner or later, that a perception is developed in the train which awakes an emotion having for its object sensorial or embodied action, upon which the rational mind is rendered instinctive again, and fit for changing its external circumstances, as happened in the instinctive mind at once, without this tedious and hazardous process of cogitation.

We see, then, that mind, as known to us, has two very distinct epochs of development, the second of which is merely a repetition of the first, with this difference, that the materials among which the mind's sensibilities take effect are different. In the first or purely instinctive epoch, these materials are sensible realities, either the surrounding organization or the external world; in the second, these materials are not sensible realities, but only ideas or perceptions of such, not necessarily implying the surrounding existence of their objects. These ideas, the mind, by the use of its sensibilities of the first epoch, acquires the power of developing within itself; and, finding some more suitable to its nature than others, of piloting its way through them to some new sensorial state, as a bee ranging over a garden, by the constantly changing states of its sensibility in the proximity of different flowers, pursues, often in a very direct course, the train of such as have saccharine nectaries.

The tenor of a purely instinctive life as that of a common bee, on the occasion of such an excursion as that alluded to, I would conceive to be something of this sort. When the light and heat around its hive increase to a certain degree, it becomes highly animated, that is, its mind becomes strongly change-seeking. It is happy in changing its existing state, and, where various changes are possible, it always prefers that which relieves its existing want most perfectly, or makes it most happy. This it does, not by any cogitation or internal comparison of various perceptions arising in its mind, each having its own hazards or advantages which are judged of by the bee, but by accomplishing those voluntary movements immediately demanded by the different states of its feeling in various regions of the garden, which are induced by the proximity of various flowers, sunshine or shade, heat or cold. It flies, because an uneasiness, existing when it is at rest, is replaced by a feeling of pleasure when it is on the wing; and this way or that way whither the feeling *always immediate* is a sensation of most vivid gratification. It pursues its course towards this flower, and not towards that other flower, because the air, or rather perhaps the radiant medium around this, acting on its expanded sensorium, intoxicates it more fully than the medium around that. Arrived at the flower, by the harmony of things, it finds honey there. At meeting such an accident, the little thing becomes mad with delight. It buzzes, squeezes in, swallows, and sips, as if it had never tasted honey all its life before. Having emptied the nectary, it finds no happiness in remaining longer. It is change-seeking again, and, guided as before, it enters as it were upon a new life again, without either anticipation or memory to occasion disappointment or relaxation of its activities. It plunges into another blossom, buzzes, squeezes in, swallows and sips, and then flies away. Its life is thus determined, and its body guided in its wanderings, by a sense which corresponds to our respiratory sense more nearly than any of the four proper to the encephalon. I do not mean to say that the bee is blind, or that it has the sensation of blackness as it flies along. Its eyes, though certainly most unfit for accomplishing the optical refractions by which the perceptions of the forms and distances of external objects become possible in our minds, evidently indicate that they are constructed in relation to the medium of light, and no doubt are very valuable organs of sensation. But to suppose that these organs give the bee perceptions of the visible distance and forms of objects, would probably be no nearer the truth than to say that the insect was blind. A bee's eyes seem to consist of a number of pyramids filled with radiant matter, and united at their apices to a principal nerve. When the bee's eye fronts a coloured object, its previously existing state must be changed; and how far the sensation or change in its state of sensibility, induced by colour, may be its guide in determining the directions in which it is to fly, it may be possible to discover. But, upon the whole, it would perhaps be more accurate to conceive, that the sense by which a bee's life is guided, is like that by which a man should be guided who lived in light where no definite objects were present, and moved through different atmospheres, some common air, some hydrogen, some vital air, some air mingled with carbonic acid, some intoxicating gas, each atmosphere emanating from one aperture, and, according to the pleasantness or uneasiness which its respiration occasioned, containing a greater or less quantity of the things good for maintaining life around the aperture whence the air emanated. In purely instinctive aquatic animals, this respiratory sense is replaced by the sense of smelling, or rather we should say by tasting, since smelling in a liquid medium, that is, deriving a sensation from the presence of foreign particles in a liquid, is strictly tasting; and in more perfect species we find this sense maintaining its ground against the eye, even when the latter has a very perfect organization, which shews plainly enough, how little power the mind, even of a pointer dog, has of forming and contrasting ideas or perceptions, compared with its disposition to move in obedience to changes in its sensibility, most truly of the instinctive class; for the sense of smelling by which the dog is so willing to be guided, only produces states of sensibility which have a sort of pleasing or painful delirium in them, but nothing calculated to awaken or sustain a train of thought. I by no means intend to assert, however, that many inferior animals are not rational as well as instinctive. To deny this is to make a most abortive attempt to exalt human nature, and to mistake its true differential character. It is admitted that other animals as well as man, are capable of those mental acts wherein cogitation consists, yet their mental constitution differs in kind as well as degree, from that of man; and to render this manifest, it is only necessary to attend a little to the constitution of human nature.

Man is quite capable of existing in instinctive states of enjoyment or uneasiness, perfectly similar to those of the bee, his whole mind being occupied in moving his body, or in possessing a certain state of sensibility, which is the cause of that motion. Almost every morning, when we awake from *sleep*, we move some voluntary muscles before we have become sensible either of our own existence or that of any thing else. An act of mind has been accomplished unnoticed and unknown by us, yet, doubtless, this movement had a cause, and that cause could be nothing else than an uneasy state of sensibility, gratified by accomplishing a change in our position. Nor are such states of mere feeling, without accompanying cogitation or knowledge, confined to torpid states of the mind. Not sleep only, but bliss, begets oblivion, into whose moments consciousness and memory dare not penetrate. As there is only a certain range in the state of the radiant medium which is fit for visi on, and light too strong, as well as light too weak leaves us unable to see external objects; so there is only a certain range in the state of our sensibilities which is fit for being accompanied with reflection on what is going on.

But states of engrossing feeling, or of introverted perception, are very precious; they are to the mind like vista-points to the traveller, on which he reads a legend inscribed by some former pilgrim; and as it would be better to be borne between such stations on eagles' wings than on mules, so is it good not to be always occupied in reasoning and doubting, provided that, by speeding our cogitations, we do not run the hazard of deviating. Now, so admirably is the mind constituted in reference to enjoyment, that if we start from a state of feeling which is true happiness, and, when the mind seeks change, travel on in the train of reason in the same direction, the next state of feeling at which we arrive will be happiness again, of the same quality as the first. By speeding our cogitative processes, then, to the extent which a just perception of truth permits, we gain the greater number of vista-points in our day, and are more happy without suffering any loss. But, let it be remarked that this relationship between emotions, which makes all the members of a series to be happy or unhappy when all are developed by the just process of perception lying between them, and extended in the same direction, does not so much arise from any thing in these perceptions, as from a continuity in the absolute state of the mind, sustained in these successive times of action, the perceptions being merely wings of truth bearing it on, and suffering it to expand into an emotion of delight as often as truth finds a resting-place. This flight, however, is rendered necessary only because every spot of earth is not a resting-place for truth. Hence the mind, when it is not pressed by organic necessities, and when the habit of forming false perceptions of things has been subdued, must become almost a continuous current of happiness, cogitation (or a mixture in the mind of truth and error, of happy and disagreeable feeling) being superseded by the intrusion of error being prevented. This is a state of things, however, very different from that which the necessities of human life commonly demand. Reason, like gravitation, is something to which, at the surface of this earth, we must have constant respect, else we stumble and fall. It is a sense in the mind not less precious than an eye in the body; yet as it is only because the mind dwells in darkness that an eye is of any use, so is it only because the mind dwells in ignorance of truth that reason is of any use. Reason is only the means of attaining an end, viz. the development of a certain state of sensibility which is denominated happiness, and the only value of reason arises from the value of happiness. If true happiness could be attained in greater quantity without the use of reason, than by its use, reason ought to be made to give its place to that mental occupation which gave more true happiness. But in the present circumstances of our existence, this cannot possibly be done. Right happiness can only be obtained by a discovery of truth, and by possessing a mind stored with truth; and truth can only be discovered, and the mind stored with it, by the use of reason. Hence reason is altogether invaluable. Yet if these views be just, it is only good in so far as it gives rise to internal goodness, which is the only genuine substratum of true happiness. Science is but a human attempt to gain knowledge, and knowledge is only memory, which is a fleeting thing; but goodness is a state of the mind's essence spontaneously permanent when once it has been established, a state of the mind's essence in which true happiness naturally swells up as often as the mind is not too busily occupied on external things to feel its own existence. But what are happiness and misery?

True happiness is the best state of feeling, and there can be no doubt that it results when our mental activities are conducted in harmony with our whole nature, that is, when all gratifications are sought and esteemed in that degree only which corresponds to their several ranks as proceeding from various parts of unequal eminence, in constituting that one thing wherein the unity of man, or the system of human nature consists. Upon every occasion when we feel gratified, something has happened within us which has exalted one part of our nature or other. Yet, in these circumstances, it is very possible that our nature, as a whole, may have by that existing gratification been violated and degraded, because an undue quantity of action may have been employed about the evolution of an agreeable feeling of an inferior rank, or an exaggerated value may have been attached to that feeling, and thus a deterioration of our capacity for superior enjoyment may have been sustained by the sweep which a subordinate thing has been made to take of our whole constitution. The gourmand at a sumptuous table, has more gratification in eating than a plain man with a plain dish before him ; and if all our nature consisted in that set of sensibilities named Tastes, with a suite of perceptions confined exclusively to dishes, the gourmand would, by his greater enjoyment, indicate that he had exalted his nature more than the plain man, who, during the time of his meal, perhaps neglected the accompanying sensibilities named Tastes altogether, his attention being directed to other things. Yet, most probably, the gourmand has degraded his nature, as a whole, more than the plain man; because tastes, and the perceptions of dishes, make up but a very subordinate part of our nature in its length and breadth. This being kept in view, no one will find occasion to deny that agreeable feelings are indications that some faculty or other of our nature is exalting itself, or that some event has just taken place conformable to something or other in our constitution. Yet, it may be very true that many states of agreeableness are justly entitled to the name of unnatural, because they are disproportionate to our whole nature*.

Misery is an indication that something in our constitution is lacerated. If the laceration is being healed, the misery becomes an uneasiness, which differs from the former in this, that it always concentrates around the idea of something in particular that could cause it to cease, or work a cure, while misery is an indefinite feeling, which, without any object but present suffering, often spurns away the suggestion of a cure as a thing unfit to be suggested. Thus the constitution of a family is lacerated when a son or daughter dies, or is otherwise broken off from the family; and the feeling of the parents consequent upon this laceration is, at least for a time, misery. It is not the constitution of the family only considered as a group of individuals, that is lacerated, but the constitution of each parent is lacerated, and the feeling of the laceration is misery.

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* See Butler's Sermons, 1, 2, and 3, on Human Nature.

We have seen that the process of cogitation, that is, the suggestion and exhibition of internal or unsubstantial things to the sensibility, which has a disposition to prefer certain ideas to certain others, is merely a repetition of the process of instinct in which external and real things are presented to the mind, which has a disposition to prefer some to others. In the same way this phenomenon of internal happiness and misery, resulting from cogitation, is merely a repetition of the instinctive apparatus of corporeal pleasure and pain. Such pleasure is the index that some bodily want is supplied, and, therefore, at the moment when the pleasure is felt, some corporeal part is exalted,—though, viewed as a whole, our corporeal system may be degraded. Pain, again, is well known to indicate a laceration of our constitution to a greater or less extent.

As to the instincts of the inferior animals, or those feelings which arise in ourselves prior to cogitation, a few remarks may be made. Feeling, or sensibility, is the sentinel of the body, in which there is a sleeping garrison, to be awoke according to the alarm given. As has been already stated, the lowest action of sensibility is to move, or attempt to move, voluntary muscles; and of all such actions, the easiest is to direct the senses. Thus, to keep the eye moving about, is perhaps one of the lowest or easiest actions of mind; hence it is, that the movements of the eye announce so faithfully the existing state of our feelings. The thing is done so easily, that no change in the existing state of the mind, whatever that may be, is required for this particular purpose. Were it so, the eye, like the legs and arms, would have a march of its own, confined to a few regular actions, fit for accomplishing the purposes of vision, and expressive of nothing more. But the eye is so easily moved, that almost every mental state of any force throws it into a state of paralysis, or involuntary action proper to that state; hence "the eye betrays the thought within." It is wrong, then, to suppose, that every movement of the eye is the result of what would, with propriety, be called a wish to perceive external objects. Blind persons, when their eyes possess a natural mobility, move them as incessantly as those who see, not only invariably directing them whither they are attending, but suffering them to range about, just because it is the nature of sensibility to produce muscular action, when not otherwise specifically engaged. The uneasiness occasioned by the prevention of this action is not recognized as one of our bodily desires or appetites, because it may always be gratified at the moment of its development. But were our eyes somehow fixed up, while yet we had the natural apparatus to give them motion, I suppose we should soon have a state of feeling as unpleasant as the first stages of hunger. Analogous to that which has now been mentioned, there are a multitude of other states of sensibility of a similar nature, and they have been treated of by physiologists and metaphysicians, because the change which they demand is not always immediately consequent upon their first evolution. There is, therefore, during the interval, a particular state of feeling instituted which may be examined.

Since these feelings are periods of mental existence, during which the change proper to them is arrested, as has been now stated, it follows from our Linnean character of mind, that they are states of uneasiness. They are named Appetites, Desires, Instinctive demands, &c. &c. To enumerate them all would be to select the substantives from those sentences which describe the elements of perfect "well-conditionedness" of body. The more notable are the desire of food, of warmth, of sleep, of health, of sexual union, of a particular retreat, of good air, of light, and of change or action. This last, however, is not a desire of a similar name with the others, but the development of the mere change-seeking action of the mind caught before it has found an object. It is desire in general, of which the others are so many species. These, and many others that might be specified, are simple states of sensibility, by which the mind is affected and related to its body, which is merely an atomic mass, at all times subject to the accidents of matter, and constantly tending to depart from the state in which it exists at any moment,—to grow or decay. They do not necessarily imply any consciousness, knowledge, or ideas on the part of the individual who has the desire, but merely a feeling calculated to change its organic circumstances. The whole era of the existence of each includes two periods, one of uneasy and one of agreeable feeling, which are not the less entitled to these names, because they may not be remembered, judged of, or described, by a separate action of the mind which feels them. The latter are actions of cogitation, possible only to a few of the orders of minds which experience the others.

Besides these, there is another class of conservative organic desires of a much higher order, which relate not only to the present, but the future. As the former are modifications of the desire of change, so are these second modifications of fear, or the desire of safety. By the agency of the former, an animal is influenced to determinate actions, by a demand to supply some instant want, and thus it hunts, eats, irresistibly clings to its place of local union, or when its organic wants are all supplied, frisks, sings, flutters, or plays. By the influence of the second, or the desire of safety, the immediate actions suggested by the feelings of the first class are contravened, modified, and permitted only to the extent that the desire of continued safety, or fear, in its various forms, permits. There seems good reason to believe that this second class of desires does not extend far down in the scale of animated beings, and that the runaway actions of insects and other creatures low in cerebral organization, are mere activities produced by the desire of a retreat. There is, indeed, something very vague in speaking of a desire of place, of a retreat, or particular locality, as one of the most elementary instincts; but place or retreat here evidently means particular form and substance, and every analogy would lead us to anticipate that each animal species should have a feeling of more perfect ease, surrounded by certain substances rather than others, and that the presence of certain things might make it very uneasy.

Now, many conservative movements commonly ascribed to fear, or an apprehension of danger, seem to be simple actions of the desire of a retreat. The hand approaching an insect causes it to run away in another direction, but not from any apprehension which the insect has that its life is in danger. This would argue knowledge of the nature of things, which an insect certainly does not possess. It runs because of a felt unfitness in its present place, beside so strange, novel, and uncongenial a substance as a human hand. In what manner this uneasiness in the animal is excited, we have no means of discovering. It would be most interesting could we find what it is in the form and movements of a hawk that affects the sensibilities of a chick, the day it has escaped from its shell, a period of its existence, when its knowledge, gained by experience, must certainly be as inconsiderable as its innate ideas. Doubtless, there is something physical and determinate in the form and movements, that is, the organization of a hawk and the organization of a chick, that makes the latter seek a retreat where the former is not present, and this may one day be discovered. The first step in the inquiry is to discover why some things, when seen by us, affect our sensibility at once with uneasiness or with pleasure; and on this subject some remarks will afterwards be made. The feeling, which is the reciprocal of that now considered, and still a modification of the broad instinct of collateral attachment of certain objects around the individual, is the desire of parents and offspring to be beside each other. Animals in a certain state seek to females, as at other times they do to particular retreats; a third set seek to their offspring, as the second do to their retreats; a fourth seek into the flock, as a third do to their offspring.

The apparatus of instinct, by which the lives of the inferior animals are upheld so admirably, all imaginary ills, such as anticipations of danger and death, being prevented, seems to be extremely simple, and the whole series to consist of repetitions or imitations of a few original susceptibilities. Yet so perfect is this apparatus of instinct, that when a strong power of reflection and cogitation is added to it, an addition of scarcely more than two instincts is necessary to make up the complement of the human faculties.

These two instincts, however, are of vast importance, and, independently of a very marked difference in intellectual character, evidently assign to the human mind a different place in the scale of intelligences from those of the inferior animals. Of these humanic instincts, the first is the Desire of Religion, or the feeling that there is a Superior Power, to serve whom, by particular acts of worship or adoration, is necessary to the happiness or ease of the human mind. The belief in the existence and the propriety of worshipping Deity, and of acting according to his will, so far as that is known, is indeed so obvious a result of reason, that were religion only found in civilised nation, we might trace its origin to human wisdom, rather than to the impulse of an aboriginal desire. This is very far, however, from being a just view of the case. On the other hand, the desire of religion, like other instincts, decreases with the development of cogitative power, and one must have a strong hold of human nature if he be constitutionally disposed for religion when he exists in very artificial states of society, which give birth to hundreds of temporal desires unknown to man in a more simple state, and thus, as it were, occupy and exhaust all his capacity for wishing upon the visible things around him. But during simpler states of human feeling and perception, in all ages and nations, some natural uneasiness has led mankind to acts of superstition; and that such a feeling has dictated articles of religious belief, and not that such articles are the origin of the religious emotion, is proved by the fact, that superstitions are often found where there is no mythology; while, in most other cases, the existing mythology is so childish and absurd, as could never be the parent of any emotion whatever, and much less of those often inconvenient and painful sacrifices of present good, to which savages and rude people are prompted by their natural uneasiness to be religious.

The other instinct (or emotion prior to cogitation or the discovery of fitness) alluded to as peculiar to man, is Conscience, or the feeling of goodness and of malice which distinguishes actions as virtuous and vicious. It has sometimes been thought that there is no such apparatus in the human constitution, and that our distinctions of actions into such as are virtuous, meritorious and good, and into such as are vicious, and deserving of punishment, are merely conventional approbations and disapprobations, depending on education, and the accidents of our particular life. The only argument in favour of this view which demands the consideration of the naturalist, is the assertion, that not only is moral approbation and disapprobation obliterated in some savages, but their conscience urges them to commit crimes, approves of them when they do so, and inflicts remorse when they refrain from them. A reason will appear in a few pages why conscience, or the feeling of that which is intrinsically good or bad, should be obliterated in the minds of the most depraved; but were it true that conscience approved of crimes, or voluntary actions causing unjust misery, and disapproved of goodness, or the voluntary act of diffusing happiness, then there would be no place for showing that man is exalted above the brutes, on the ground of moral constitution. I apprehend, however, that in every instance where a savage is urged to a crime, it is something very different from a moral approbation of the act which leads to its perpetration, and that the issue of the act is very different from the experience of that approbation. Thus, it is quite conceivable, that a half-starved and degraded savage, the mother of a new-born a range of conceivable modes of action, vastly greater than in any of the lower animals. By a simple wish, we can, in a moment, arrest a train of thought, occupy ourselves with another subject, or cause the mind to retrace its steps. All these phenomena, then, and others that might be mentioned, are favourable to the idea that the human mind is of a nature far more different from those of the inferior animals than they are from each other. Their minds indeed have all the characters of being of the same species; for, in every creature, they are pronounced or active exactly in the ratio of the organization of the animal considered. Man, again, his specific organization remaining the same, is capable of exhibiting extremely different and contradictory phenomena, according to the influence under which he may happen to act.

It has been already frequently stated, that most of our positive knowledge respecting mind in general, is derived from the consideration of the phenomena of matter, viewed as exemplars of the phenomena of mind. Let us for a little inquire whether we may not, by considering the economy of material action, come to some knowledge respecting the intimate economy of mental action. That of atomic action we have found to consist in the fulfilment of the tripartite law of imitation, in virtue of which a body, during the period of its change or activity, imitates first *itself*, by which specific character is sustained; secondly, *surrounding bodies*, by which harmony, sociality, and analogy with other bodies are sustained; and, thirdly, *the most perfect form*, by which an uniform direction and limit are prescribed to atomic action.

Now, the first of these influences to which a body submits, during increment, which preserves specific sameness in successive moments, is obviously an exemplar of the feeling of *mental identity*: For this feeling depends upon our ability to imitate or reproduce, at this present moment, a feeling or perception formerly experienced by us, assigning to it, at the same time, the place where the action repeated first occurred, that is the mind within. When we cannot reproduce the mental state which existed at the past time referred to, with infant, may, in consequence of a habit prevalent in the tribe, associated perhaps with particular notions respecting life and death, feel very uneasy in certain circumstances until she has committed infanticide. Her mind is possessed by particular feelings respecting one particular creature that came out of her body, and has a peculiar relationship to her, just as the mind of a polite mother is about a son and heir, or the beauty of an infant daughter. Both have particular wishes made natural to them in particular, by the existing state of society, which it is very uneasy not to gratify; and the savage, when she murders her infant, or the European mother, when she does something which makes the little one more to her liking, obtains relief from the uneasiness which existed before, and prompted to the selfish action considered. But this relief from previous uneasiness, is quite different from that welling of the sensibilities which comes on when a well-constituted heart is punctured by a sight of cruelty or injustice, or its sealed fountains opened by beholding an object of moral beauty. In this case, there is no pre-existing desire from which to seek relief. On the instant perception of a willing agent intentionally affecting the sensibilities of another, there is a liking or a disliking, a pleasure or a pain, a vivid emotion springing up in the mind, while perhaps engaged in an arid calculation, or in cold behaviour, like a spring in a desert, or a geyser among snows; or causing horror and detestation to rush out in the midst of pleasure like a lava torrent among vineyards. Certainly, the existence of conscience as a leading feature of the human mind cannot be denied; nor is it less true that other animals, when acting according to their natures, make no such distinctions among their actions.

But the desire of religion, involving the idea of another state of being, and the desire of virtue, are not the only features in the human mind which distinguish it from those of the lower animals. Its progressive quality is a most remarkable feature; but this has been often illustrated, and need not engage us now. There is also in man a breadth of agency, a range of conceivable modes of action, vastly greater than in any of the lower animals. By a simple wish, we can, in a moment, arrest a train of thought, occupy ourselves with another subject, or cause the mind to retrace its steps. All these phenomena, then, and others that might be mentioned, are favourable to the idea that the human mind is of a nature far more different from those of the inferior animals than they are from each other. Their minds indeed have all the characters of being of the same species; for, in every creature, they are pronounced or active exactly in the ratio of the organization of the animal considered. Man, again, his specific organization remaining the same, is capable of exhibiting extremely different and contradictory phenomena, according to the influence under which he may happen to act.

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Another of the phenomena of mind which consists in self imitation, is *Memory*. That such is the mode of its action, is too obvious to demand any illustration. The belief that the thing perceived by memory, and that which really happened at the time and place referred to, are the same, depends upon the perfect resemblance of the ideas constituting the recollection, and those which constituted a narration more or less full of the event remembered. The mechanism of belief, then, is exactly the same as in the case of mental identity. The object of the belief only is different, being, in the case of identity, the remembering thing, and, in that of memory, the thing remembered. The perception of an interval of time having elapsed between the act of memory and the event remembered, seems to depend upon a want of perfect sameness in the mind, as it is when engaged in remembering, and as it was when transacting the event remembered. The mind is never the same in two successive days: every new perception introduced must of necessity modify its subsequent action. When the embodied mind becomes weak in age, and similar to what it was in youth, the events of youth are often remembered as if they had happened yesterday.

Still lower in the scale of mental actions than memory is *Habit*, which also consists of self-imitations. The thing imitated in this case, however, is not a perception, or idea, as in the case of memory, but a feeling or instinct. Memory consists of a train of thought, the change-seeking sensibility of the mind being adequate to urge on from one perception to another, the order of suggestion being usually a repetition of that which occurred. During habit again, the change-seeking sensibility, or life of the mind, has only energy enough to repeat some pleasant feeling over and over again, without any evolution whatever. Habit, then, is the lowest of all mental actions. It is an unconscious mimickry of one's self, the mind being too indolent and dead to demand change. After habit, the disposition to be constantly occupied in recollecting, indicates a stationary and low condition of mental activity; and when to these we add the action of the feeling of identity, we obtain the entire phenomena of the lowest order of minds. Such habitose remembering egotists may be found anywhere smoking and snuffing; and it is really amusing to notice their minds at times when they are thrown into a state of activity according to the best of their ability to cogitate. One may be seen removing his pipe from his large lips, with a Turkish gravity, ominous of some great mental deliverance; and after due time has been afforded for the smoke to escape from within him, perhaps twenty *I*s, uttered in a tone which, to save labour, is made also to clear his throat, make their exit; after which the mortal is again found sucking the narcotic nipple assiduously as if he had exhausted himself and run some great hazard of existence, inasmuch as the light of his pipe may have gone out during the forgetful time when his mind was exerting itself. If another more highly endowed get beyond the idea of his own presence and existence, he relates some event which has happened to him in past life, using, for the purpose of concealing his ignorance of language, and in an attempt to force interest into his dull narrative, as many monosyllabic oaths and strong terms as his vocabulary contains.

But a complete self-imitation of a single feeling, as in habit, or of a single idea, as in memory, is usually prevented, even in the most torpid mind, by the development from within, or introduction from without, of collateral perceptions or feelings which draw away the mind in its successive states from a complete repetition of itself, as it existed in preceding ones. In this way recollection is changed into *simple suggestion.* The train of thought, when evolved under the least restraint, is commonly ascribed to *Fancy;* when under a conscious effort to perceive any thing, it is named *Conception.* When the material of a train of thought is neither mere matter of memory, nor a bazar of ideas such as happens to have been evolved by a random and careless procession of thought,—but when it consists of ideas successively developed one after another, according to the legitimate law of relative suggestion, the hazard of mischoosing being prevented;—the train of thought is a process of *discovery,* or it is the evolution of truth. But usually each idea, during the moment when it occupies the mind, instead of producing a single birth of one idea, truly or intuitively related to the parent which developes it, breaks down and gives origin to several. This mental weakness gives occasion to the phenomena of *Reason,* which consists in applying all the collateral ideas suggested by any one more remote idea in a train, to the essence of the mind, with a view to discover which of them is accompanied with that particular state of sensibility or emotion named *Intuition*. That to which intuition is found to belong as its substratum, is received by a law of nature as a truth, provided always that the preceding idea out of which it has arisen be true also. This second idea is, in fact, involved in the first; and *a demonstration* is merely a particular explanation, in which every thing in the fundamental idea is neglected, but that circumstance to which the demonstrator's attention is directed. The act of deciding in favour of one idea in preference to others, constitutes *Judgment*.

When the successive ideas relatively suggested are not complete evolutions of each other, but contain only a certain quantity of repetition, then they are commonly said to be *analogous*. The grouping of such as are perfectly similar under one general idea, constitutes the process of induction and *generalization*. The process of arranging into parallel positions such as are only similar to a certain extent, and of developing the general method or idea involved in them all, constitutes demonstrating by *analogy*, or generalizing *analogies*. Analogies take their origin from the unity and variety of nature. The perfection of the human understanding consists in the ability to discover what things are, and what are not analogous; and the perfection of knowledge consists in having all the truths which the mind possesses, disposed of in their positions of analogy or relationship to each other. By this means the mind is made a model of the universe.

A process of reasoning, then, consists in coursing the track of truth in the field of error, and reason is a process which can co-exist only with the possibility of erring. In minds so constituted or circumstanced, that the liability to err does not exist, reasoning becomes evanescent, and imagination is identified with discovery. That strong change-seeking state or life of the mind, then, which, in a state of ignorance and inconsiderateness, pours itself forth in the random streams of imagination, "watering its own desert," is the same as that which makes discoveries, when, in the possession of much knowledge, the mind proceeds by the scent of truth. The yielding to a luxuriant power of suggestion, previous to the acquisition of knowledge, among which the living mind may be safely suffered to run wild, is not suitable to the exigencies of our present narrow circumstances of existence—

> "'Tis a false nature—'tis not in
> The harmony of things."

The conceptions of imagination are indeed sometimes more beautiful than any thing which the person beholding their beauty may know to be certainly true. But that only arises from the mind's ignorance of what really exists, and from its noble ability to shoot up into the air of truth, beyond the reach of its own experience. In such things as the mind feels to be beautiful, there always lies the possibility of truth. Were it not for the contamination which intuition suffers by that converse which, in every process of reasoning, it is necessitated to hold with error, there is good ground for believing that the feeling of intuition would merge into the feeling of the beautiful. The present alarm, which is generally taken at the suggestion of any thing in science which, without learned pretension, presents a countenance of undisguised beauty, is one of the many indices of a twist in the perception of the nature of things with which the minds of many men of science are covered, like the clock of Strasburg.

The phenomena of cogitation which have now been mentioned, then, it appears, are processes as similar to the self-imitative actions of an individual nascent body as any thing can be conceived. The system of emotions or social activities of our mind, is still more perspicuously an exhibition of a mode of action which a nascent body is exemplifying when assuming the forms of those that surround it; the object of which law is to preserve a sameness of state in all the individuals of the same species. The whole economy of the social emotions is to effect the interlacement of the individuals of a community together, so that the advancement of one shall either occasion the exaltation of others along with it, or these others attempt to bring down again the ascending individual to their own condition. The emotions are diffused by an immediate imitation, on which little need be said, as it has already been fully recognised by philosophers under the names of Sympathy and Antipathy. When two individuals meet, one of which is in a state of emotion, the other submits to a parallel or direct imitation or sympathy only when the status of both in the moral and intellectual scale is more or less the same. If there be a considerable difference between the moral temperament of their minds, an inverse instead of a direct imitation ensues. The sympathy remains, but it is not an analogous or parallel feeling, it is an antipathy or inverse feeling. Reasoning from the analogy of nature, this phenomenon of emotion clearly shews that human nature is mutilated and has lost its entireness. For this phenomenon, though exhibited by two individuals, is quite analogous to the states of activity in corresponding parts of the same body, not in two bodies; which indicates a state of things, as if the number of entire human constitutions distributed to the race were less than the number of individuals in that race. To illustrate this, it may be remarked, that when the constitutions of two individuals are entire as to any particular department of mind, then there is a parallel feeling between them. An emotion in the one causes the other to fall into a true sympathy or parallel and similar state of feeling. When, on the other hand, any one is seen in a state of emotion by another whose constitution is deficient as to that particular department, then there ensues an inverse or antipathetic imitation. The deficiency is supplied by the opposite of that which is wanting. This grand law in the nature of mind is very curiously embodied in atomic phenomena, which those who have studied the preceding parts of this work will discover for themselves, and which could not be well pointed out to others. Thus, when an individual sees another in distress, the observer, if he possesses a mind well constituted as to benevolence, immediately falls into an imitation of the distress which he looks upon, and, feeling distressed, is (independently of that cogitative process by which the fitness of relief is evolved) moved to relieve. Cogitation, independently of sympathy, though by a slower process, leads to the same line of conduct. When prompted to do right, our constitution almost always gives us two strings to our bow; when prompted to do wrong we find only one, and this generally snaps after it has impelled us to the deed, leaving reason lacerated, and the heart unstrung.

Further, it is true that we do not weep only with those who weep; when our constitution is entire, we rejoice with those who rejoice. Were the soul of every individual whole, there would be a general and direct sympathy, and such we may observe in the economy of some of the inferior animals which live in society. But because the haleness of our natural constitution no longer exists, and can be learned only from history and the internal perceptions of a *beau ideal* to which that history responds, there are a great many feelings induced by the observation of persons in particular states of mind which are not direct and parallel feelings, or such as are commonly called sympathetic, but antipathetic feelings, developed under the influence of the circumstance, that the individuality and entireness of the first mind is felt to interfere with that of the second, who, in such a state of things, falls into the reciprocal or consecutive state of feeling. Thus, the desire of glory observed in any one by a person having a like individuality and entireness of constitution, is imitated in the observer in a direct and parallel manner: he feels the desire of glory too, and thus he is led to a generous emulation. But when any one feeling the love of glory is observed by an imperfect mind, by one who, wanting that in his constitution which could ever make him glorious, cannot seek for glory, in such a mind the love of glory seen in another gives birth to the inverse state of feeling, that is, the desire that the glory-seeking individual were reduced to his own level. Instead of feeling emulation, the lacerated one feels envy and jealousy, species of revengeful and resentful feelings, seeking the destruction of the particular object which excites them. The imitation is equally exact in both cases, but in the first the sign of the induced feeling is, as it were, positive, in the latter negative; in the former case, the quantity of glory-seeking is doubled, in the latter, the addition of a second quantity to the amount tends to destroy the whole. This direct and inverse imitation of feeling may be every where observed. Thus, the devotion of a clergyman leading the service of a church (when that devotion is full and unaffected, for mimickry stops with the mimic) may be seen impressed upon the fellow-worshippers in the deepest and most beautiful manner: even the deaf and dumb are not beyond the reach of the penetrating influence. A street-walker, again, moved by curiosity to enter in, whose mind is incapable of the direct impression, may be seen, immediately when he has come into the presence of the devout people, expressing in his countenance all the features of an inverse imitation, and without any knowledge or evidence whatever of the character of the persons looked upon, may be found accusing or accursing them as hypocrites. His feeling is, as before, a species of resentment and revenge, seeking the destruction of the devotion which he looks upon, and which he is unable to respond to otherwise.

Religious sympathy, technically named the Communion of Saints, Love, Gratitude, Benevolence, desire of the affection of others, are so many parts in the mechanism of emotion, whose direct action is to produce assimilation among the individuals of the community affected, the whole group advancing together in the progressive development of essential goodness of mind, and the possession of happiness, which is the vital feeling of that goodness.

The insulating emotion, or that which operates to preserve the individuality of each person in the community, is Self-esteem, without which, in the proper degree, a human nature, at least when existing in human society as it is, never can be entire, for otherwise it will constantly be exposed to contamination and degradation. This esteem is not in any degree piercing soul, is a falcon that flies only at noble game, whose flight is short and sure, and which by the time reason can come up, it is found perched upon its prey with an expression of sadness, pity, and benevolence. Mere passion again is a hobby on the arm of a fool, flying even at the wind which unhoods it, and shewing only the love of flying and the intent to do mischief.

But self-esteem is the quarter in which the human mind has received its most fatal laceration. The good feeling which resists the solicitation to degradation is now found replaced by an insulating pride. A wholesome resentment calculated at once to save us from degradation, and to impress the offender with a sense of his own, is replaced by revenge or the desire to bring another into a state of distress as an ultimate object. This emotion is the most mysterious phenomenon in human nature. It is such that one who knew the general economy of things, but had not seen human nature as it is, would feel inclined to deny upon oath that such a state of mind could exist, or, if informed that such was really the fact, he would endeavour to explain it as an accidental aberration of mind analogous to insanity. This does not satisfy, however. Revenge is a firm cogitative state of mind, fertile in designs to obtain its object. It is a sustained desire, having its period of uneasiness and its period of gratification as distinctly pronounced as any other instinct whatever; nay, there is a parching quality during the existence of the first, and a grateful pungency in the second, which shew too clearly that revenge has a strong hold among the sinuosities of our distorted constitution. As to its origin and natural history, one is tempted, on philosophical grounds, to believe that such an anomalous feeling is surely an upfilling or impression derived from some powerful and cruel mind opposite in its nature and dispositions to the Supreme Mind, and permitted to exist for some purpose connected with the upholding of a moral and retributive administration.

So far, then, the phenomena of the human mind, both cogitative and sensitive, are found to be imitated, typified, and illustrated by the phenomena of sensible bodies. We found, this is only equivalent to saying that we believe because we understand; for the evidence of a truth is merely its expansion to the extent necessary for the mind's perceiving it; and the *economy of evidence* or the expansion of truths to the end that they may be believed by minds like ours, ignorant and prone to misconceive, is one of the most delicately beautiful features in the phenomena of mind. An useless profusion of evidence is never granted; and those who demand double evidence generally fail to find any. By this admirable arrangement, a finite mind is made capable of entertaining a much greater quantity of independent knowledge, each part of which has a value of its own. For, by receiving a locality in the mind, not as a thing admitted there on its own account, but because it is evidence for the truth of something else which only the mind has respect to, a truth is degraded, and loses general value and authority within us. Those who are always insisting upon more evidence than is enough to content a well constituted and broadly perceiving mind, generally believe at last, when they happen to believe at all, only because an excess of evidence cloys their disposition, and prevents the action of the *desire of scepticism* which is amongst perceptions much what revenge is in morals; for scepticism seeks the destruction of truth, as revenge does that of happiness. The sceptic labours under a mental leprosy, an exclusion from the entire constitution and economy of mind, no less serious than the man of malice intent. To receive an idea, having learned from the source whence it has been derived or somehow otherwise, that it must be true, and without demanding it to be arbitrarily expanded in the mind, that is, without demanding secondary or double evidence, the evolution of which may, in the present circumstances of our understanding, be impossible, indicates a most exalted and entire state of mind; and to this the history of great men in all ages has borne witness.

It has been shown, however, that if the phenomena of atomic action be illustrations and exemplars of those of mind, we may expect to find a still more vivid impress of the Divine influence upon those states of our mind which are evolved by our social nature, than upon those which are evolved by acts of self-imitation. We may expect to find it more strongly impressed upon our emotions than upon our cogitations. Now, it is most certain that all our relative emotions, one after another, as they are developed in the mind, come forth stamped with a certain pleasant or uneasy feeling, which is universally one and the same in nature, and applies itself without change to emotions of most opposite qualities, and gives an approval, or disapproval, of every action affecting the sensibilities of others, which the mind proposes or feels disposed to accomplish; and on comparing this influence with the intention of the Supreme Mind, we find that they correspond entirely. By the discoveries of intelligence alone, as well as by the aid of revelation, thinking men have called this conscience of the mind's intentions the *voice of God* within us,—an expression which, if the principles now contended for be received, is not altogether a figure of speech. It is this impression which distinguishes, in the mind, actions into such as are virtuous and such as are vicious. Mental disturbances may occur to prevent the impress. "Virtue, though lost to our perception for a moment, however, is immediately perceived again with distinct vision as before, as soon as the agitation subsides. It is like the image of the sky on the bosom of a lake, which vanishes, indeed, while the waters are ruffled, but which reappears more and more distinctly as every little wave sinks gradually to rest, till the returning calm shows again in all its purity the image of that heaven which has never ceased to shine on it *."

It has been said, in a former page, that misery or distress which spurns hope away, always indicates an essential laceration of our constitution. Now, the most intense misery that has yet been discovered, is induced when the mind, on the ground of its own agency, sets up its judgment, and indulges its disposition to act, in opposition to this impression derived from conscience, which is now supposed to depend upon the immediate presence of the Supreme Being.

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* Brown's Lectures on the Philosophy of the Human Mind, vol. iii. p. 573.

The consequence of such an unnatural act must obviously be a laceration of our constitution, in relation to God; and it is very reasonable to suppose that such an injury should involve the mind in more acute misery than any other. It is, indeed, quite possible that a considerable interval may elapse between our voluntary offence against the felt authority of our constitution, and our self-occupation with the misery we have given rise to; but the laceration, and, as it were, the matter of misery, are immediately produced. Such great misery, however, only re-acts upon great hopes. There are many small hopes connected with this life, which are, as it were, below its regard. A man, by setting himself up against his conscience, may make a deeper and a deeper laceration in his constitution every day, and yet remain under the inspiring influence of a multitude of small hopes, which, because they are small, easily find their objects, and thus succeed in making him happy, according to his idea of enjoyment. He may hope for luxurious living, get it, and be happy in his way—conviviality, equipage, men and women to his taste—such things he may freely wish for, hope to find, get, and enjoy. But this state of external activity of which he is capable, speaks nothing against the existence of the misery in his nature, which though then, in as far as his private feelings are concerned, it may be slumbering, is yet all the while growing big in his breast, to suffocate and bleed within, during the era when he is denied indulgence in those social activities by which at present he perspires his uneasiness away, and preserves himself for a time from feeling the congestion at his heart. When our organization is lacerated most deeply, there is often a period of delirium and pleasant dreaming, during which certainly the mind is rather enjoying than suffering. The internal knowledge of the misery produced by the organic lesion, does not come on till Nature feels truly the breadth of the injury she has received. A man in sound health, however, notwithstanding the symptoms of enjoyment which he beholds in such a case, cannot help regarding the delirious or insensible being as only an ill-animated corpse; and were our minds in sound health, we should deem a mind acting without or against its conscience, as a corpse of spirit ejected from its place of life in nature, and having the most horrible feature of an impossibility to die.

The phases which both lacerations display are the same. There is in both, first a period of misery, which is not felt by the individual himself,—then a period which is felt. During the insensible period, the misery existing re-acts, not upon the feelings of the sufferer, but upon those of others. For a time the wicked man scatters abroad his misery, and smites others with it. In the second period, memory begins to reproduce and beget within his own heart all that he has done in the first; and it is truly fearful to think what anguish a human mind, thus lacerated in its constitution, as related to the Supreme Being, may suffer. Our bodies are indeed to our minds, what the governor is to the steam-engine. They keep our feelings always within that range of intensity which our organization can bear. But when our minds shall be insulated, there are many evidences that their susceptibility of happiness and suffering shall be far greater than we can now conceive. In sleep, when they are often somewhat insulated, one sometimes finds that a dream, the accidents of which are in themselves perfectly trivial, is the occasion of the most distressing horrors. It consists with the known phenomena of the human mind to suppose, that if, by the use of its own agency, a mind had refused to obey those yieldings to goodness which naturally arise from the Divine Presence, when the human constitution is entire, and has thus placed conscience beyond a barrier, within which all that mind's activities and pleasures, and recollections are enveloped—the mere breaking down of this barrier—the mere restitution of the entireness of human nature to that being—the simple re-establishment of conscience, in the remembering and self-imitating thing—is the consigning it to the greatest of all conceivable misery. It is, indeed, more impressive to the general run of minds, because it brings to view more obviously the Divine sovereignty and authority, and is therefore better suited for our ignorance, to treat of the present and future destiny of mind as depending upon insulated acts of authority on the part of the Supreme Governor of the Universe. But in that glorious or dreadful era, when from our positions in eternity we look back upon time (if we may do so), then, even when beholding fulfilled all the retributions of life, it is probable that, in as far as the development of new moral mechanism and the institution of new spiritual laws are concerned, we will feel "Is this all!"—It is only because we are ignorant of the things that are now and have been ordained before the world was, that we fail to discover the natural trueness of the things revealed to be hereafter.

The relationship between the intuitive sense or the instinct of truth, and the moral sense or the instinct of goodness, is very interesting. Both are approbations of certain products of mind, and disapprobations of certain other products of mind. The instinct of truth, however, has a smallness and pliability in it which the other wants, and by its activity in breaking cover, proves itself well adapted to be the lion's provider. When I see a benevolent stranger supplying the wants of some miserable vagrant, or a great and a good man, whose existence is a blessing to society, hazarding his life, in equal danger, in a voluntary attempt to save that of some worse than useless wretch, the moment such actions are beheld, the instinct of goodness, a sensibility pungent and blissful, is awoke, which sweeps over the soul, and, careering above reason, pronounces that there is goodness in the heart of such ones who engage themselves in relieving distress, and that it is delightful to behold it. Shortly after, in such a case, however, the instinct of intuition running in, reason comes into its small but useful play in the mind, and proves to the conscience, or instinct of goodness, that both men, by their actions, may cause more distress than they assuage. Thus moral feeling is supplied with a dress suitable to the present fashion of things, thereby losing her Minerva-like grandeur, and coming into keeping with the other parts of the composition. Such accidental transformations of our moral feelings do not, however, in any degree disparage the preciousness of this faculty, any more than the faculty of sensible perception is disparaged by the seeming revolution of the heavens. Our particular locality requires the introduction of a correction as to direction of moral approbation in particular cases. A broad law of testimony, adapted, not to any particular locality, but to the universe, must be modified to suit this world; but this only proves the grandeur of the feeling of goodness, and that it was created in reference to eternity and the universe, rather than to time and our present place.

The fact, that moral feeling and conscience are weak or altogether obliterated in some minds, is an argument in favour of the view which has now been advanced as to its origin. That a particular education, entire ignorance of the nature of things, and habitual abandonment to wickedness, should occasion insensibility to the natural influence of the Supreme Being, it is most reasonable to believe; and if this happen, the loss of the feeling of goodness, according to the view now advanced, naturally follows. Hence, also, it obviously results, that when seeking for the existence of conscience, or the feeling of right and wrong, we must examine specimens of the human race which are of the most entire and exalted constitution, not savages and degenerate individuals whose constitution is most deeply mutilated.

Perhaps it might be difficult to shew, simply by the character of moral approbation itself, that it is an emotion of a quality different from other pleasant and elevating emotions generally; but this may be satisfactorily done in reference to its opposite. For remorse differs from all other emotions which have to do with cogitation. It rather agrees with the painful periods of appetites, which are periods of constitutional lesion. There is nothing but suffering in it. All other feelings commonly known by the name of emotions, however much uneasiness they involve, have also a certain agreeableness. Some minds find melancholy more agreeable than gladness, and such may be seen composing their eyes and lips when the pleasantry of some friend has discomposed their sadness sooner than nature would have it. Fear is an emotion so pleasant that many persons devise little achievements chiefly for the sake of the fears which they bring into play by exposing themselves to danger. Hatred has a latent heat or a chill in it that imparts to it an agreeable freshness. Revenge is, to some persons, fearfully delightful. Cruelty gives pleasure. Whatever emotion is natural to the human creature, is not without its own gusto. But who will say that remorse is not perfect distress? It is a dragging of the soul at the chariot wheels of memory, every verdant spot of past existence being burnt up by its track.

The view which has now been advanced of the nature of conscience, makes moral obligation to be a part of the constitution of man, arising essentially from the place which God has assigned him in the scale of beings, and out of that noble feature in its constitution, which makes it not impossible for him to imitate the Supreme Being, by the possession of goodness and intellectual and moral happiness. Thus the intention of the Creator, that there should be in the universe intelligences multiplied according to the laws of matter, and in due time capable of emerging from their organic connexions, and of leading an existence similar to intelligences which have had a different origin, is accomplished by the institution of the law, that these organic intelligences, while yielding to the laws of material developement, should ever recognise the Divine Presence, by their feelings of virtue and vice, and be at once kept under moral obligation and responsibility, and fitted, by an education in knowledge and virtue, for a loftier and more happy place in the scale of being. These conditions enable us also to understand a very interesting feature in the nature of the inferior animals. As they are obviously not intended for other states of existence than that in which we now find them, and have powers of perception and feeling just fit, though very admirably fit, for enabling them to conduct their by good or bad conduct, as has been already shewn, becoming the highest conceivable reward, or the most agonizing punishment. It were good if we could learn what sorts of crime mere organization prompts to; and this may be done by observing the inferior animals; which throws light upon what seems at first inexplicable in the economy of the brutes: For we sometimes see the exhibition of instincts which have a criminal aspect.

A fox, for instance, spreads a bait for poultry in the yard in which he is chained. Having spread the bait within stretch of his chain, he affects to go asleep. The fox has a sensorium which enables mind to accomplish such acts of ingenuity. He has no consciousness of virtue or vice. He is hungry. But he is not guilty of deceit. Such a mode of acting is as much according to his nature as any other mode. The poultry are not deceived; for they do not count upon honesty in the fox, but go by what they see, and, knowing less of the fox than he knows of them, are caught. The fowls, in their turn, knowing more of worms than worms do of them, seize the reptiles, and assimilate their molecules to their own bodies, while abundance of young worms are in the course of growth and development. It may be confidently stated, that any attempt of man to develope more benevolence in creation than that which is developed already, would be productive of more misery than that which exists. For any thing, then, that appears to the contrary, that which exists is the greatest quantity possible, the element of the material creation being as it is. As to virtue and vice, viewed apart from moral agents, they are nonentities. To no terrestrial species but man, does the mechanism which makes one action virtuous and another vicious extend. If the fox got his food otherwise than he did, then he would be no fox. Should any one say there ought not to have been foxes in creation, if it really emanated from a Creator such as theists contend for, this is equivalent to saying that there should have been no notion of deceit in man, or that man and other animals should have been organized after different models, which would have been a state of things quite contrary to the unity and harmony by which all things are related to each other, and would have afforded the objector a strong argument for atheism or polytheism. It is impossible to conceive any state of things such that another may not be imagined. But it is very ridiculous that a man should find himself admirable enough to discover how the present creation could have been made better than it is, and yet not be content. It is much to be regretted, that theologians and naturalists do not understand each other's subjects better than they often do. This would save many apologies for Nature on the part of the former, and many errors of greater consideration on the part of the latter.

It is very unsatisfactory, however, to treat of the Physiology of the Human Mind, of all subjects the most important and interesting to the naturalist, in such a hard and runaway manner as this, to which the figures at the top of the page urge. Instead, therefore, of continuing such general notices of the relationship of matter to mind, by selecting some one class of mental phenomena for more minute investigation, I shall endeavour to shew that knowledge of the structure of mind may be acquired by such help, which explains, in a most satisfactory manner, phenomena at present regarded as arbitrary and unaccountable matters of fact.

When speaking of the qualities of the best design possible, it was said that, besides working out the end proposed by the designer, the intermediate phenomena constituting the evolution ought to be such as mind signalizes by the word BEAUTIFUL. Let us, in a few pages, inquire whether the views which have occupied us in this work, do not throw much light upon this class of mental phenomena. It has hitherto been disregarded in our progress, but certainly none is better entitled to a minute consideration; for the lives of the thoughtless are commonly nothing more than blind pursuits after the pleasing and the beautiful; while those of even the most cogitative and conscientious are still in a great measure regulated by their taste. Yet let us not place Taste in opposition to Conscience. Taste is a man's natural and legitimate guide for securing his own happiness, as conscience is his guide for securing the happiness of others.

In entering upon the phenomena of Taste, it is necessary to distinguish between that pleasing emotion consequent upon the discovery of fitness, and that grateful sensation which accompanies the beholding of a beautiful object, or the listening to a beautiful succession of tones. The former is one of the common products of cogitation and reflection; the latter is a feeling anterior to all such intellectual actions, and is immediately consequent upon that change in the optic or auditory nerve which occasions sensation. The feeling of beauty is coeval with the perception of the external object said to be beautiful, and is nothing else than a peculiar sensation. Co-existing with the perception of an external object, there is in the mind a peculiar state of sensibility, as the substratum of the perception; and, according as this state of sensibility is agreeable or not, we say that the object exciting it is beautiful, graceful, or grand, or of an opposite character. During the evolution of these phenomena, there is evidently no place for the discovery of any specific fitness or adaptation to some particular purpose in the object named beautiful. It very often happens indeed, that objects which have much beauty have also much fitness, compared with compositions of the same class which are less beautiful, because whatever is beautiful is in harmony with nature in general, and whatever is fit is in harmony with nature in particular; hence, just as things which are equal to the same thing are equal to one another, beautiful objects are often identical with fit objects. Further, it is obvious that any thing viewed in relation to a particular purpose, for which it is unfit, can never please. But many things are beautiful, in which there is no fitness for any particular purpose; and others, though fit, are felt to be beautiful anterior to the discovery of their fitness, and just because there is a something unknown in them which pleases the eye or the ear. This seems so obvious as to demand no further illustration.

Let it be granted, then, that there are many things which, on the immediate notice of them, we pronounce to be beautiful, graceful, or grand,—what is the particular mechanism by which, on beholding them or listening to them, our mind is involved in that agreeable state of feeling, of which any external object is represented as a cause when it is denominated beautiful, graceful, or grand? The reader will doubtless expect that I am again to call in the aid of the law of imitation to explain these phenomena; and accordingly, the view now to be insisted on is, that the emotion of beauty arises from an imitation taking place in some part of our constitution or other of that which is said to be beautiful. If this be made out in reference to sensible beauty, it will be most legitimate to infer the same in reference to moral beauty. Let us, then, endeavour to detect the phenomena which take place during the development of beauty of sight and sound, and the external elements in the beautiful object on which the feeling depends.

In looking over a heterogeneous collection of objects, all of which are beautiful, it may at once be discovered that the emotion of beauty excited by them derives its origin from one or other of two sources, or from both combined. Either we find the object to be beautiful, being regarded at the same time simply as a form, a colour, a coloured form, or a sound; or we find it to be beautiful, being regarded as expressive of some fine state of intelligence or sensibility. Some things are unquestionably beautiful, simply because they have something in their shapes, tints, or tones, which pleases the eye: no ulterior object of the mind's regard can be discovered as a cause why it is pleased. Other objects, again, evidently have a beauty, chiefly because they are found to be expressive of embodied mind, either of tenderness of sensibility, or goodness of heart, or grandeur of intelligence. Of the former sort may be instanced the images of a kaleidoscope, and the analogous figures in Gothic and Moorish architecture, the coloured fringes of double refracting crystals, the figures on drapery, and many others that might be mentioned. All these are very beautiful, and yet no one can discover any reason why they affect the mind with admiration, but because they possess certain forms and colours, whose generic characters may indeed be discovered; but concerning which nothing more can be learned by simple observation, than that the object contemplated; because it possesses a certain form or colour, pleases the eye. The case is very different when we look at a statue of a Venus, an Apollo, or a Minerva, at a well proportioned column, at a poplar tree or a drooping willow, at a ship under full sail, at a river glittering under the moon-beams, at a white cloud towering above the horizon, or at a distant mountain. Such objects as these awake the emotion of admiration, because they are expressive of certain admirable states of mind, while they possess, at the same time, such forms and colours as are not calculated to displease the eye; for were this the case, it is of course impossible that they could be regarded as beautiful.

If the feeling of sensible beauty be the effect of an imitation of the beautiful object by some part of the constitution of the being who feels the emotion, there can be no doubt that this part of the constitution must be the sensorium, just as in the case of the feeling of unseen moral and intellectual beauty it must be the essential state of the mind itself. Now, without pretending to describe the forms of the illuminated images in that part of the head where the sensations and perceptions take place, which correspond to external objects seen, nor the state of vibrations propagated from the ear when tones are heard—without pretending to describe any particular region of the encephalon as the sensorium, or to be more particular about it than to avail ourselves of its general structure,—it is obvious that the imitation contended for is made out, if it be found that those sensible objects are most beautiful which are most harmonious to the structure of the sensorium and the cerebral mass; and, *pari passu*, that those moral objects are most beautiful which are most harmonious to our moral constitution, according to its entire and original destination. The sensorium, it has been shewn, we are to regard as a symmetrical tissue of radiant matter: hence it is obvious that the image of a symmetrical object can be much more easily constituted in the sensorium, or imitated by it, than an unsymmetrical or irregular one. The image of an unsymmetrical or irregular object must demand a greater effort or sensorial displacement. Further, until a body has resolved its parts into symmetrical positions, it is obviously not in a state of physical repose. Motion is therefore natural to it, as rest is to a symmetrical mass. Hence it follows that symmetry, with that harmonious relationship of parts which indicates that they belong to one individual, must give rise to a form in harmony with physical action in general, and that of the sensorium in particular, and most capable of being imitated in the sensorium; and therefore such objects ought to awaken the emotion of beauty, and that most strongly when the forms of their surfaces, and relationships of their lines, are harmonious with those of the sensorium. But it must be the beauty of inactivity and repose, for, having attained symmetry, the mass has attained the limit of its intrinsic action. Such as are not symmetrical, again, requiring at once a greater effort of mind to disturb the sensorium, and to retain their images in it, and having yet to move ere they have attained the limit of their action, ought to be symbolical of animation, or expressive of mind, as something whose co-existence, along with the atomic forces of the mass, restrains the action of the latter, and prevents the evolution of symmetry, or the limit of physical action, and that to which body is always tending when unrestrained. By increasing symmetry, then, always preserving at the same time unity of relationship among the parts, we must gain beauty, but produce at the same time the expression of repose or deadness. By diminishing symmetry, we must gain the aspect of animation.

Now, it is obvious that every visible body consists of superficies and edges, that is, expanded, illuminated, or coloured parts, and outlines; and it may be viewed by the eye, either in relation to its surfaces or its outlines, or in the mind's regard of it both may be included. What lines and surfaces, then, are harmonious with those of the sensorium and cerebral tissue?

Independent lines, each having an unity of its own, to be conformable to the structure of the sensorium, must be parallel to each other, for all the analogous edges of similar rays in a tissue of radiant matter are parallel. Lines at right angles to each other are equally conformable to the structure of the sensorium, and still more capable of being perfectly imitated or represented, but they are mutually dependent or parts of one individual; for lines at right angles are analogous to the consecutive edges of a radiant atom, or the consecutive parts of an octonate molecule or perfect ray. So much for the relationship of lines.

As to the superficies, in a tissue of radiant matter, they are all equilateral triangles. The symmetrical area, therefore, capable of being most perfectly seen, consists of two equilateral triangles united by a side, that is, a lozenge or rhombus of 120° and 60°, and this is the superficies which, considered simply, must have greatest beauty. Were we indeed to draw, in ink, upon white paper, the outlines of a square, a lozenge, and other simple figures, it might be difficult to say which was most pleasing, and, perhaps, no two persons would agree. One mind would, in fact, have respect to the area included by the lines; another to the lines themselves; and, as the beauty of one or other depends on dissimilar features, perplexity could only be expected. But let a lozenge, square, circle, &c., be painted of one uniform tint, without any dissimilar outline, and laid upon a neutral surface, and every one, I should think, would decide in favour of the lozenge. Here the mind contemplates the superficies, and fixes upon that as most pleasing, which is seen most distinctly, and with the least uneasiness or effort, from its being most conformable to the structure of the sensorium, and from an illuminated or excited image of it being constituted in the optic region with less disturbance of the quiescence of the remainder, and a smaller destruction of the unity and symmetry of the whole, than had the superficies observed been of any other form. A lozenge is perfectly symmetrical, however; it is therefore expressive of deadness and repose.

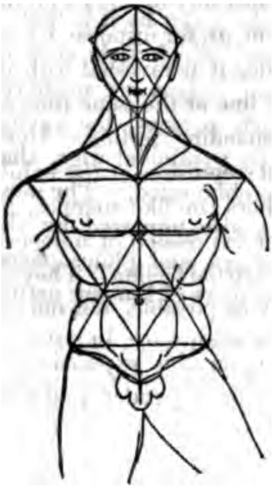
After the lozenge itself, in point of harmony with the sensorial tissue, is its half, obtained by cutting it along either diagonal. In this way we obtain an equilateral triangle all whose angles are 60°, and an obtuse angled triangle, all whose angles are doubles and halves of the former. Two such triangles constructed upon opposite sides of one line, therefore, develope an area, which is, after the lozenge itself, capable of being most perfectly harmonized with the sensorium. After the lozenge, therefore, this ought to be the most beautiful superficies, a number being grouped, so that the mass is symmetrical. Taken by itself, however, it is not symmetrical; it is therefore expressive of animation. By drawing an axis, it is divided into two triangles, each containing one angle of 90°, one of 60°, and one of 30°. It may also be developed by cutting an equilateral triangle into two by a perpendicular let fall on one of the sides, and then applying the two entire sides to each other. The equilateral triangle, then, ought to be the rudimentary superficies of mere formal beauty; the right-angled triangle, with one of the acute angles 60°, the other 30°, ought to be the rudimentary superficies of animated beauty.

But so long as we regard superficies merely, whatever be their form, we have not yet arrived at that which, among visible things, is truly symbolic and expressive of mind. There may be animation expressed by colour and superficies, but it is sensual and physical animation, which has nothing to do with intelligence, grace, or grandeur.

What visible thing, then, may we expect to be expressive or symbolical of mind? It is obvious that we must fix upon an axis rather than an equator, that is, a line rather than a superficies; for the axis is that to which all the other parts are subordinate, and on the particular characters of which all the qualities of the other parts depend. A physical line also, considered by itself, is a polarized axis, a body capable of the greatest activity; and, when the first era of its activity is over, by the uniting of its opposite extremities, its action is changed, but not destroyed; there is, then, an independent circulation instead of a soliciting polarity, and the form resulting is the circle, which is obviously the emblem of unity and unchangeableness. The reader may perhaps feel disposed to reject these ideas, but is he able to disprove them? "Errare, Mehercule! malo cum Platone . . . . quam cum istis vera sentire."

A straight line is the emblem of pure perception. When the whole object seen is viewed by the mind as one line or column placed in a perpendicular position, or position of individual symmetry, then the expression given by it is that of independent perception, or intelligence, which feels none of the yieldings of social nature. Hence judges are made columnar by robes being hung over their persons, the waving lines of their necks being filled up by pyramidal wigs, that the graceful lines of humanity may be obliterated. The same carriage and analogous drapery are also imparted by the painter and sculptor to apostles, senators, and philosophers, the head and neck being left free, that more of humane nature may be expressed.

To superinduce beauty of form upon this expression of severe intelligence, the column must be expanded and contracted in different regions symmetrically, in relation to the organization of the human body, whose sections are wholly composed of *equators of animation*, such as have been described. Now, in expanding an axis in relation to this superficies, it is obvious that the line on which the expression of mind depends must have the obtuse and acute angles of the lozenge at its opposite extremities; because the opposite extremities of a line, which in physical combinations must be regarded as a polarized axis, possess consecutive polarities; and negative polarity always demands greater expansion of surface than the corresponding quantity of positive polarity. Hence the column must be expanded, so that the angle contained by the expansion at one extremity shall be as nearly as possible 120°, while the angle contained at the other extremity shall be as nearly as possible 60°. Thus a plane is developed, such as has been already described, which consists of two right-angled triangles laid symmetrically together by their hypothenuses (which now represent the axis), and of such a form that the shorter of the sides, containing the right angle, is double the length of the hypothenuse. When these triangles are laid together, so that the right angles are not opposite each other, then there results a column again, or rectangle. If we wish to construct the human form of various styles of symmetry, we have only to combine these expanded axes, whose dimensions are taken from the measures of the spine, in a very simple and geometrical manner; and by the outlines, angular points, and lines parallel to the shoulder line thus obtained, the relative magnitude, position, and form of the most eminent parts of the head, body, and limbs, are at once determined; and by varying analogous parts through the same angles, the whole person, whatever be his style, is kept in harmony with himself.



To proceed, then, with the attitude or axal line of the person, it may be remarked, that the statue formerly presented to the mind in a columnar aspect, when thus expanded, expresses the symmetry of the human form, as well as that of independent perception; but, in consequence of the axis being obscured, as an object of the mind's regard, by the development of a certain amount of formal or superficial beauty, much of the penetrating and perceiving expression of the figure, when it was regarded as an obelisk or column has been sacrificed. There are few persons, however, who can separate so far between the intellectual and social of human nature, as not to feel uneasy, rather than pleased, in viewing a human form, which, though beautiful, yet, in consequence of the perfect rectilineal uprightness of the axis, expresses only independent intelligence, destitute of all susceptibilities of humane feeling; and when, as in some ancient idols, sexual and social developments are added to this rigid perpendicular carriage, the image becomes unhuman. By the straight vertical line which represents the personality of the figure, the statue is made very powerfully intelligent, but it is at the same time made insulated and unsocial. By the development, in these circumstances, of formal beauty, and especially by the exhibition of some decidedly sexual or social form, as, for instance, by modelling the bust like that of a female, it is invested with the apparatus of affection, the personal line at the same time expressing a destitution of the corresponding feeling. Hence the mind experiences an emotion of repulsion at the exhibition of such an incongruity. Soldiers, in like manner, are required to stand erect to convey the expression of independent observation and want of social or partial feeling. They are also made to move as symmetrically as possible, not only on account of the fitness of symmetrical evolutions, but that an army may appear more truly a self-moving engine of destruction, and not a group of spontaneous warm-hearted men; a state of things which would be expressed, if the symmetry of the mass were destroyed, and each moved according to his own way. When a company of men is vehemently animated, however, it is quite against the order of things to array them as a symmetrical mass; and, accordingly, such violence to nature changes the feeling of natural and momentary resentment into settled hostility. The pertinacious adherence to symmetrical evolutions tones down fury into veteran anger, giving rise to a state of collected strength and determined perseverance, which, doubtless, are more fit than fury for the fatigues, and disappointments, and cautious movements of an effective campaign. Men are, therefore, made good soldiers by destroying their natures; and it seems to be delightful for an old soldier, relieved from the command to be always in an unnatural position, to find his nature returning, as he wanders about according to his will. Affection comes back with such freshness, as soon as recoil after the violence done to it is permitted, that an old soldier seems always seeking for his wife and children, though he knows that he has none to find. Thus war is made to glorify the gentleness of humanity.

The rigid straight line, then, does not express our nature, but only a passive and pure perception of the nature of things, which is but a part of humanity. That, whatever be its particular form, which represents the personality of the human mind, must obviously be the vertebral column. For, first of all the organs, it makes its appearance in the embryo, it determines the subsequent evolution, and retains supremacy in the expression of personal appearance through life. We have seen that when this line is viewed as a rigid vertical, the head being in a conformable attitude, and the legs in that position which most naturally supports the body, the mental expression is that of independent perception and passiveness to the nature of things. One line, if vertical, is symmetrical, when considered by itself; it does not exist in relation to any other line; the person whose mind it expresses, does not live in relation to other beings; he is insulated, and unsocial. But when a line becomes bent, to re-establish symmetry and entireness of nature again, another similarly bent must be found. When the vertebral column becomes bent, then, to restore symmetry and beauty, another vertebral column having an analogous bend must be brought into existence. The person expresses now a social nature, and is capable of sympathies or antipathies, according as the cerebral columns of the two *individuals*, in each other's presence, are parts of the circumference of the same circle, or of distinct circles. As has been said, the circle (or symmetrically curved line returning into itself) is obviously the symbol of unity, entireness, and unchangeableness. Two persons inclining towards each other, are expressing, according to the laws of nature, though unconsciously to themselves perhaps, that they are of a social and mutually dependent constitution; and the circle or unity and entireness of that order of beings depends upon each stooping to such a degree as the circle to which they belong demands.

Hence we see the cause of that laughter which is drawn out of us, when two comic individuals sitting opposite each other, instead of inclining or retiring at the same moment, move in a parallel manner. Laughter is the act of our social nature breaking down *within* us for a moment, and it is excited by the exhibition of a momentary destruction of our nature observed *without* us. When one smiles, his mind is at that moment aspiring no higher than it is; when he laughs, his constitution is at that moment falling down. Excessive laughter is as bad for the mind, as it is sore for the sides. If our taste were quite pure, a laugh would be the most severe of all reproaches upon a representation of human nature by the sculptor or painter. A visible object which causes laughter is always low, and it is only the worst of our nature that it can please. Accordingly, we may find, in reference to the carriage of the persons now treated of, that laughter is excited by a destruction of the unity of the axis. In every case where a stoop is seen, our social nature is drawn out. The stoop of the Medicean Venus and of Paul Pry both imply a social nature, and draw out ours instinctively as soon as we look upon them; but there is a difference. The Venus has only one graceful bend forwards, soliciting protection and love; yet withal so dignified, that before one dare to think of protecting or loving, he feels the necessity of being worthy. By infusing so much mental beauty and grace of feminine feeling into her attitude, by making the expression of her whole person lovely, the sculptor has been able to dispense with much formal womanhood, which, however beautiful in life, is too particular for marble; and, except to artists, displeases by its unfitness, when it has the coldness and hardness of stone. In the monstrous character alluded to, on the other hand, the man of always anxious politeness is seen stooping forward, convoluting his hands, as if washing them in the streams of goodness which flowed from the individual whom he addresses, his body bent as if it were broken in three pieces, in such courtly presence as he seems to find himself. His spine is put off the perpendicular at the very foundation, to shew his solicitude and dependence on the person addressed; it is made a little convex towards that object, to shew his aversion at finding himself engaged in such humbling confessions and anxieties; and his head is made perpendicular, to shew his independent intelligence and understanding of the matter. Thus he stands, trying to appear to do good-natured things, proving himself to be one of the most exquisite fools; a [illegible] in the [illegible]. Suppose it were in real life, one would feel great [illegible] at such an expression of degraded humanity; and because it seems impossible to apply such an inconsiderable creature to the circle of human nature at all, one feels disposed to put him out altogether. When the exhibition is seen on the stage, we laugh; and this is equivalent to the former feeling; for such laughter is comic cruelty. The ungenerous feelings which we bear such a being, are, however, his own work. The busybody excites intoleration, even in the persons to whom he makes himself over, because he addresses himself to our selfish, instead of our benevolent or truly social, nature. He aims at awakening vanity and other personal conceits in the person he addresses, thus working quite against his own wishes, constantly throwing himself more and more out of view, by making the man he flatters a greater and a greater egotist. The Venus again addresses our benevolent and truly social nature; we say that her person is extremely engaging and beautiful, because her attitude expresses qualities of mind, which it is more congenial to our mental constitution to imitate, than those of the other class. Such is the character expressed by the Medicean Venus; but when the flexure of the whole person is increased beyond what she displays, then we have nymphs and figures which become too solicitous to be regarded by the mind as beautiful, other things remaining the same. When a line, then, is a rigid perpendicular, the individual seems destitute of social character altogether, having neither sympathies nor antipathies. When it has one curve, sociality of nature is alone expressed, a sympathy or antipathy being announced according to the direction of the concavity or convexity of the curve. To develope the expression of the sociality of the human mind, and yet preserve the expression of its entireness of personality and independent feeling, it is obviously necessary therefore to make a line of double curvature, retaining so much of the straight line or perpendicular carriage as shall still sustain the expression of pure perception or intelligence. By such a state of things, the soliciting expression of one part of the axis is supplemented by the withdrawing expression of the other. One part indicates that the person seen requires protection and affection—the other, that these feelings do not occupy all the mind within, but that the independent part can protect the sensitive part; and the whole intimates that the observer must be worthy of receiving the object viewed under his protection before he dares.

The elementary visible object, then, which expresses the constitution of the human mind, is a line of double curvature, or waving line; but it is obvious that the two curves cannot be arches of the same circle or curve, and that the neutral point cannot be the centre of the line. For reasons which have been lately given, when tracing the superficies, which expresses animated formal beauty most perfectly, it follows that one of the curves must be more expanded than the other, and the neutral point must lie towards one extremity; and this departure from perfect symmetry, to be most beautiful, must be in a very simple ratio, such as that of 1 to 2. Now the curve thus traced out is most perfectly displayed by the human cerebral column, which forms the basis of the organization; and whenever it is seen entering into the composition of any object which, considered as a whole, is calculated to be pleasing,—as expressive of the human mind, gentle, social, and intelligent—it awakens the perception of extreme beauty. A human form of perfect beauty may be drawn by rounding off the binate right-angled triangles, formerly described, in their just positions, and of their just magnitudes, in relation to the spine, by these lines of double curvature and their parts. It is almost incredible how often they are repeated both in the bones and soft parts; nay, not only do they exist where they appear, but it will be found, that almost every group of features which is beautiful may be measured by one, as every mass of light or composition which is most pleasing may be measured by one of the quadrangular forms of animation already described.

It appears, then, that an animated being, whose carriage axis or symbol of personality is a vertical straight line, has an overhead expression of pure perception, that is, knowledge of the nature of things, truth, justice, uprightness, or that character of mind, by whatever name we call it, which refuses to violate the laws of the universe, by yielding to the solicitations of some present feeling or particular circumstance. By imparting a single flexure to this axis, it loses its entireness; individual symmetry, and unsocial beauty, becomes impossible. By imparting a double flexure in opposite directions, individuality is restored as at first; but now the expression of the severity of pure intelligence is softened. The mind expressed is no longer a passive observer of the nature of things—no longer a judge who refuses to feel mercy, because there ought to have been no crime. The mind now expressed is social, and feels the particular state of particular things. The line of its perception is curved into its own specific nature; and its intelligence consists, not in rightly perceiving only, but in rightly feeling also. It is no longer able to judge *of things* by the laws of the universe, but according to its own specific laws of sensibility, regulated by the perception of truth and justice, which continues to be expressed by the contour of straightness, unobliterated by the gentle flexures introduced. When the axis acquires such double curves, that its relation to the straight line is no longer perceived by the mind, then this expression of truth and justice is lost. The mind announced, is one of excessive sociality, on the one hand—and excessive pride, on the other; for the expression of sociality and independent or insulating feeling are of course developed in the same proportion, when both curves sympathize in their forms. Such a curve, then, represents a mind which is constantly disposed to interfere with the social feelings of others, which is of an excessively proud, and, consequently, of a resentful and revengeful nature, and which has no regard to truth and justice. This character is commonly named a Devil, and the curve which has been described is in the form of a serpent. Hence a serpent is the natural animated symbol of a devil; and such appears to be the history and form of the lines of intelligence of grace and malice.

Were we, in illustration of these views, as to the visible elements of formal and mental beauty and deformity, to select any particular object for examination, as, for instance, the human countenance, we should find those few principles which have been advanced constantly coming into play. 1. That symmetry in unity is the cause of beauty. 2. That formal and sensual beauty depends on the expansion of superficies of the required shapes. 3. That the expression of mental beauty depends upon the symmetry of lines, severe intelligence being indicated by the straight line, the intelligence and sensibility conjoined, which constitute the beauty of the human mind, by the line of double curvature which has been described; and absolute unity and unchangeableness by the circle. 4. That animation by mind is expressed by departures from positions of symmetry. This last circumstance, whence the picturesque in scenery derives its origin, is fertile in most curious results. Thus the eye, when symmetrically situate in the centre of the opening of the eyelids, expresses nothing but the essential unity of mind arising from the circular and spherical contour of the eye. In this position, it merely gives a vacant stare; but as soon as the symmetry is destroyed (in a vertical plane, good) emotions are expressed. Thus, when the optic circle is moved upwards, our eye expresses hope and veneration; when it is depressed below the position of symmetry, it expresses considerateness and compassion. But the fact, that matter expresses a more thorough penetration by mind; when the parts of a mass are prevented from assuming positions of symmetry, is still more curiously displayed in the various styles of the accessories of human life, such as dress, &c. which are displayed by the human species in different stages of mental development.

The more fully pure intellect is developed in any society, the more numerous are the attempts made to destroy symmetry; and, in highly artificial states of society, when mankind become solicitous of mental supremacy, and almost incapable of the feeling of the naturally beautiful altogether, even the natural symmetry of the person is disfigured to gain expression of mind or intellectual authority. Savages, again, who feel nothing but beauty, constantly endeavour to increase the symmetry of their persons, and, to an intellectual observer, make themselves very unhuman. Thus, they compress the forehead, till its form becomes similar to the chest; and not being alive to the perception of intellectual unity expressed by the head when in the simplicity of nature, without salient or angular parts, they adorn it till it becomes an imitation of the trunk. Not only do they compress the forehead to imitate the chest, but knowing that what makes a man formidable is his arms and legs, the former when in a state of action being extended more or less in a horizontal direction, they at once increase the symmetry of their persons, and probably gratify some heroic notions, by transfixing the cartilage of their nose by a horizontal bone or arrow, and hang from their ears pendulous masses, which, taken with the transverse bone, obviously make the head symmetrical with the trunk, by furnishing it with horizontally extended arms and vertical legs. Moreover, as they do not feel the intellectual expression which colour destroys, they cover their faces with patches, and lines of colour, of such forms and tints, as, were they not on a human face, are directly calculated to please the eye by their beauty, or to excite to revenge by their incongruity. All these are so many attempts, according to the laws of nature, to develope beauty, the person being considered as a corporeal mass; and it is only because they destroy what is beautiful in the expression of mind, that we are entitled to regard such actions as barbarous. In the case supposed, then, by Sir Joshua Reynolds, of the European " who has cut off his beard, put false hair on his head, bound up his own natural hair in regular hard knots, as unlike nature as he can possibly make it, and after having rendered them immoveable by the help of the fat of hogs, has covered the whole with flour ;" and of " the Cherokee Indian, who has bestowed as much time at his toilet, and laid on, with as much care and attention, his red and yellow ochre on particular parts of his forehead and cheeks, as he judges most becoming ;"—in this case, the European has done what would make him very ugly, and the Indian what would make him very beautiful, if they were not men. Both are acting not in any degree capriciously, but according to laws of human nature, strongly felt by both, though unsuspected by either. The European, to make his form expressive of mental acuteness, and to show his penetration by mind, has diminished the natural symmetry of his person, and by so doing has shewn that there is something wrong in his perceptions; for were it not so, he would find that the human form, in the grandeur and beauty of its natural development, is more fit than in any other state to express at once the amiableness and intelligence, the godlike gentleness and dignity, of uncorrupted human nature.

With regard to the relative beauty of the two sexes, it is obvious, according to the views here advanced, that, independently of all masculine partiality for it, the female possesses more formal beauty than the other sex, for the superficies are more perfectly expanded, the whole contour is more wavy, and the tints more beautiful. In studying costumes, then, the best opportunity of comparing these views with nature is obtained by having regard to those of females; and if this be done, it will always be found, in every age and nation, that where beauty of personal form is chiefly regarded, and behaviour is all that is demanded for intelligence and virtue, the costume becomes extremely florid, every prominent feature being surmounted with some salient and symmetrical lacework or plume, which fills the eye with beauty, and permits the mind to forget the intellectual esteem which is due to the being from whose naturally graceful carriage the mind of the observer is led away by a show of fascinating superficial beauty. But a lady in a very florid and symmetrical dress, however fascinating she may find herself to be, is only a Cherokee goddess. Whatever gives much formal beauty, takes away from the possibility of much mental expression. A prince or a peer, invested in all the beautiful insignia of his rank and order, if considered as a single-handed man, is by no means so formidable as a monk in his coul, or an unshaven radical in rags.

Colour, because it belongs to superficies, is capable of exalting formal beauty in a high degree; but, for the same reason, it is incapable of expressing mind. Nay, even though the tint vary frequently, still if there be not lines developed on which the mind may spontaneously settle, no appearance of mental expression ensues; and if none of this be gained, while, at the same time, the attention of the observer is attracted to the new feature added, some of the expression which depends on the other features must be lost. The theory now advocated (that the feeling of beauty is proportional to the perfection of the sensorium during the time of the sensation, or to the ease with which the form or colour of the external object is imitated in the radiant tissue of the brain), enables us to anticipate what colours must be most beautiful and serene, what most ugly and disturbing. The atomic movements by which green, blue, azure, indigo, and violet, are conducted, being less violent than those by which red, orange, and yellow, are conducted, the former, when seen by themselves, ought to be more beautiful than the latter. Those colours, also, ought to be most beautiful, when viewed in juxtaposition, which belong to analogous regions of the chromatic axis; for the symmetry of a chromatic display demands this arrangement; and it has been already shown, when treating of vision, how great an effort the eye makes when viewing an object of one colour to generate its complementary colour in juxtaposition with it. From this circumstance, the whole suite of colours may be made beautiful, simply by placing such as are less pleasing in their true relationships to such as are beautiful. Thus, orange viewed alone may be displeasing, but let a larger surface of an indigo tint be laid beside it, and forthwith the orange seems beautiful, because orange and indigo are symmetrical or consecutive colours, during the viewing of which the eye is in a very perfect state. In the same way, scarlet, viewed by itself, is a hot uneasy colour; but a blossom of this tint, surrounded by blue-green leaves, is very rich and pleasing. Crimson, by itself, excites inferior admiration to that which it awakes when seen on a cloud expanded on a field of azure. Thus two consecutive colours placed together mutually exalt each other. A colour which, when seen by itself, is beautiful, has the power of bringing into favour a displeasing one when introduced along with it: while that inferior tint, in its turn, elevates the charms of the beautiful one to which it owes its own ability to please.

Music serves admirably well to illustrate the same phenomena. Those who paint their faces, wear large ear-rings and nose-jewels, thus proving themselves alive to the feeling of physical beauty, but dead to that of mental expression, ought obviously, if they have music at all, to have very symmetrical music, consisting of pulses, bearing to each other the most simple proportions. Accordingly, we find, that the rudest music (when not connected with the excitement of war), consists of monotones, thirds, fifths, and octaves, recurring at regular intervals, in perfect keeping with anticipation. The music of civilized nations, again, to be most gratifying to their state of perception, must have the perfect harmony and equable pulsation of the notes destroyed to a certain extent, and one note must be made to run into another, to produce the effect of a line, and develope mental expression. Accordingly, we find, that polite music consists of two parts working against each other, the one calculated to sustain the emotion of beauty, the other to give the expression of mind to the composition. The symmetrical, or simply beautiful harmonic pulsation, is retained as the fundamental part or the bass. Over this there is laid an ever-varying chant, which often, in the compass of a few seconds, runs over the chromatic scale. The buss (and of course the chant also, when it becomes simple and symmetrical) makes the music capable of pleasing the ear: the chant is the vocal pantomime, to which we owe our interest in the opera.

As might naturally be expected, the phenomena of expressive music are merely repetitions of those of speech, in a sort of universal language; and, by a simple inspection, we may see, that the lines of tone, having certain expressions, have the very same form as the cerebral lines, which we have already traced, that have the same expressions. Thus, it has been shewn, that a straight axis of the attitudé, which involves the repetition of many parallel and transverse straight lines, such as that of the nose, the mouth, the horizontal axis of the eyes, a quadrated contour of head, &c. is expressive of a grand unsocial mind. Accordingly, it may be remarked, that such characters usually speak monotonously. Every one feels, too, that the sustained monotonous ringing of one church bell is grander than the same quantity of sound produced by a chime. The opening of an overture, also, in a succession of monotones, to which new sounds are gradually added, is more grand than any other. In like manner, it might be shewn, that wailings and plaintive airs, triumphant, gay, and satirical sounds, are produced by tones proceeding along the very lines, which, when embodied in the human form, convey the same expression. Thus, were a line drawn through the series of notes, which represent a wailing sound on paper, that line would also represent a mouth (the external organ of speech), expressing sadness. Graceful speech would, in like manner, give waving lines, like those which have been shewn to express human nature in its more amiable and intelligent state. So perpetually do these lines recur, that there are at least four developed in the form of every well-modelled mouth, along with one or two permanently smiling lines, on the lower confines of the under lip. Excessive range of intonation, again, is obviously analogous to the serpent curve; and, although the science of the sensible expression of mind can only be truly studied from the exhibitions of the painter, the statuary, and the player; yet, as to its application to life, this branch of the same general laws of embodied expression, which is developed by speech, seems to guide us fully as often to the truth as the indications of attitude and physiognomy. The latter we do not forget to attend to, making them express what we wish to be esteemed, rather than what we truly are within; but our speech is always apt to betray us. A man of insinuating serpentine intonation of voice, announces by his tones, that there is an excess of social feeling, and a want of the natural feeling of justice and uprightness in his constitution, more truly than if all the lines of his countenance were tortuous together.

According to these remarks, (most hurriedly announced) the art of the sculptor, painter, musician, player, depends upon the use of a few general formulæ, according to the artist's conception of his subject, and knowledge of the laws of nature. But, it is obvious that the views advanced are incomplete, if they do not explain the beautiful in architecture also, for it is indisputable, that besides fitness as a temple, a dwelling-place, or a monument, a piece of architecture may range between beauty and ugliness, just like any other object that affects our taste at sight. Now, since the feeling of sensible beauty depends upon the capacity of the sensorium, to imitate or represent the external object which excites the sensation, it follows that we may anticipate what styles of architecture shall be most beautiful, by viewing the sensorium itself as an architectural model. Analysing it, then, we find, as has been already done, that it consists of a multitude of surfaces, which are equilateral triangles, and of lines which are parallel and cross at right angles, and of individual parts, which are of course pyramids. There ought, therefore, to be three beautiful styles of architecture; first, *the rhomboidal*, in which the eye fixes upon the areas, which are parts of equilateral triangles; secondly, *the prismatic*, in which the mind fixes upon the lines, which cross at right angles, the areas being merely rectangular intercolumnations; thirdly, *the pyramidal*, or that which is of all the simplest and most rudimentary, and might be regarded as the hemi-rhomboidal. The rhomboidal and pyramidal style, according to the views already advanced, in so far as an edifice is purely of this kind, must only express formal beauty without mental expression. The prismatic, for a like reason, must possess the beauty of mental expression, of which the pyramidal also becomes capable, when the triangular surface ascends into the obelisk. The maximum of beauty in all of them, must depend upon that blending of the beauty of mere form, and that of mental expression, which is conformable to the nature of man, who has both an eye to respond to visible forms, and a mind to respond to mental beauty. In the rhomboidal and pyramidal styles, therefore, as they express mere formal beauty, the expression of mental beauty must be gained by accessories to the edifice; while, in the prismatic style, the beauty of mental expression is embodied in the mass of the edifice itself.

Now, in harmony with these three styles of architecture displayed by the sensorium within, we find that mankind, seeking for the beautiful, have fallen, in different ages, into three grand styles of architecture,—the Egyptian or oriental, the Grecian, and the Gothic. In the most ancient times of our species, when, to judge from their colossal enterprises, the human sensorium seems to have had a firmer texture than at present, and to have been less under the influence of intelligence, men built edifices unconsciously in harmony with their own organization. Just as every animal has a natural instinct which prompts it to be surrounded with certain forms, having some relationship to its organization rather than any other forms; so man, seemingly under the influence of some natural liking to such forms, surrounded himself with pyramids, and pyramidal frusta, and, in his moments of mystical feeling, placed himself on tripods, or frustular tetraedral. It may be said that this is very fanciful, and I will not dispute it, because it is with the fact only, and not the theory of the phenomenon, that we have to do; and, certainly, it must be admitted, that the Egyptian style accords perfectly with our anticipations of the pyramidal style of architecture. Its unfitness at the surface of the earth, however, for the construction of hollow buildings, soon gave occasion to its being departed from, and to the substitution of perpendicular, instead of sloping walls. Upon this arrangement also, to which probably considerations of fitness led, a more perfect display of beauty may be induced than the first; and what is remarkable enough, almost every feature of beauty in this style, may also possess an architectural fitness. By bringing the pyramidal or Egyptian style into a state of fitness (the building being supposed a shell), with the action of gravitation, it passes into the prismatic or Grecian. This style consists of vertical and horizontal parts, the pediment alone retaining on the great scale the combinations of the pyramidal style. Its symmetry is consequently that of lines, and its beauty that of mental expression. A Grecian temple, when entire, and surrounded by its columns, is a sanctuary, surrounded by a marshalled host of upright worshippers of nature. Symmetry gives it beauty as a mass of stone-work; but as mental expression is gained by departures from symmetry, and as every column, taken by itself, has the expression of an intelligent and firm being, when thrown into ruins and its symmetry destroyed, a Grecian building gains in grandeur what it loses in beauty. Thus every downfall brings life like dust upon the ruins which remain.

The circumstance that the beauty of the Grecian architecture depends upon mental expression, and not on mere expanded form, renders it capable of being reduced to almost any size, without changing its expression, or destroying its grandeur. If a Grecian building be as high as a human figure, nothing but vastness is lost by the reduction. The expression of the Grecian model is the same as that of the actual edifice; it is at all times also perfectly intellectual and pure; for the expression of sensuality depends upon the beauty of expanded superficies. It is also independent of all accessories but ground to stand upon. A group of Grecian buildings is at once a place of temples, of groves, and of statues. From these circumstances, then, we are enabled to see how well it belonged to the Athenians to develope such a style of architecture.

So far, then, for the pyramidal and the prismatic styles, but where, it may be asked, are we to find the rhomboidal, or that whose beauty depends on its areas, and which, exclusive of accessories, is destitute of mental expression? The Gothic style supplies every quality which we could anticipate. The individual parts of it belong to the order of the kaleidoscope. The angles developed everywhere are, as nearly as is consistent with fitness, those of the lozenge. The whole of its beauty, therefore, depends upon accessories and upfillings; for the lines, viewed as such, are unsymmetrically related, and are unpleasing. The mere skeleton of a Gothic cathedral is nothing better than an iron-like cage for keeping dry bones and relics in, owing any grandeur it may possess merely to its vastness and the necessity enforced by gravitation, when the body of building is great, of developing columnar masses and parallel lines. When a Gothic building is left without florid upfillings in its arches and areas, the eye looks completely through it, and it is merely something standing between us and the sun. But the case is very different when the rhomboidal style is preserved, only in the details, becoming as it were drapery, and the building as a mass is formed of two transverse sets of columns, and reared up to a towering elevation. The florid and beautiful forms seen on every region which the eye may fix on, make that region beautiful, *while* the columnar vertical lines displayed by the towers and spires infuse mental expression into the whole. The mind embodied is, however, far away, compared with that seen in the Grecian, and the excess of parallel and want of transverse lines, deprive a Gothic building of the expression of unity. This, however, would enable it to gain the picturesque, if the prevailing symmetry did not prevent it. It has been said, that any part of a Gothic building in the florid style is beautiful when viewed by itself. But the beauty being that of symmetrical superficies, is so cold and inanimate, that one may observe constant attempts to superinduce animated forms Thus everywhere there are niches, which either contain statues, or are supplied with them by the mind of the observer, which has indeed even a better effect in imparting mental expression to the part of the building observed than if the statues were present; for in that case we are apt to condense all our perception of expression upon the statue, and leave the surrounding mass as cold and unconscious as before. In the upfillings of windows also, we can constantly trace, especially when the Gothic style is just emerging from the Saxon, areas whose forms have a very solemn expression to those who have inspected the hollow stone-coffins, which were much in use at that time, and are quite similar to those in or around the windows alluded to. As the style of the architecture improves, we may also observe that the lines of these sepulchral forms are purified, and a constant tendency may be discovered towards the introduction of the quadrangle of animation, composed of two right-angled triangles, laid together by their hypothenuses, as has been already described.

But, still, with all these accessories, a Gothic building, unless its mass be very vast, is apt to be looked through instead of looked at. It still wants scenery; to be where it ought, it must be seen among mountains and lakes, and azure and clouds, and "bosomed high in tufted trees."

The Gothic style is, in architecture, just what richness of dress is in drapery. Hence, we see that it naturally rises out of an age of great chivalry, as the Grecian does out of an age of great intelligence. Under the influence which the emotion of physical beauty inspires, the gallant knight knows no fear, nor can find enterprizes great enough to shew the zeal of his love and admiration. Transferring this emotion to religion, he sets on foot a crusade against infidels or stone-quarries, and rescues the holy sepulchre, or builds a most majestic cathedral, among the recesses of which he may tremble on his knees, in the presence of some petty ecclesiastic, who has intelligence enough to know how to assume the aspect of grandeur of character. Hence we see, that as the Grecian is most fit for modern purposes, so is the Gothic most unfit. The latter, when it loses its vastness loses its grandeur; when it ceases to be florid it ceases to be beautiful. And, certainly all modern attempts to sustain the Gothic style are either very ugly (although perhaps the elevation on paper was pleasing enough), or else they are merely very pretty, having to sustain their character of beauty against a want of grandeur, and a feeling of unfitness and uselessness in many of the details of the building. Let it not be denied, however, that a Gothic cathedral of sufficient vastness, and with all its accessories, is at once grand and solemn, and very beautiful; and that it should have such a character, even to an extent of which the Grecian is quite incapable, fully appears from these principles of taste.

The three styles of ornamental architecture which have now been mentioned, have undergone changes suitable to the development of the minds of the people who built, but they are the central forms from which the others are only to be regarded as departures produced by particular circumstances. Thus the Romans, having a demand for vastness and strength, applied the semicircular arch to the Grecian style, and to compensate for the loss of beauty thereby sustained, added a greater quantity of florid work. The Saxons being in a state in which mere sensorial beauty is alone perceived, embellished their columns and arches with zig-zag lines and lozenges; while, in the age of chivalry, the western Europeans, still more alive to sensorial beauty, and still more regardless of fitness and mental beauty, applied the lozenge-angles to the arches themselves.

These views might be extended to a great length, and, however far extended, every statement would be found an illustration of the position, that the mind experiences an emotion of beauty when the atomic movements in the sensorium, excited by the external object said to be beautiful, are in harmony with the quiescent parts and natural constitution of the sensorium,—when the form of the external object can be imitated in the excited parts of the sensorium, without demanding a state of incongruity between the excited parts and those which continue in a state of repose,—when the visible or audible object without is easily modelled in the nervous tissue within. Hence it is obvious that some objects, considered merely as forms, seem less beautiful than others, only because they depart farther from the constitution of human nature as it is now. Could we only take a disembodied and impartial survey of creation, doubtless every thing which had not some unfitness in it would be most beautiful. It is impossible therefore for us, while communicating with the external world by our present sensorium, to form any just conjecture as to the absolute amount of created beauty that may be perceived by our mind, had that mind the power to enter, as it were, into the object contemplated, or to derive a sensorium from it, possessing the possibility of being perfectly modelled after it. Therefore it is evidently absurd in man to disesteem any object in creation which has fitness for its own existence; or to say that it is unworthy of a Supreme Creator, because, forsooth, it does not awake the human emotion of beauty. A man may justly, in such circumstances, say that such an object was not created to please him, but that is all. How amusing, then, would it be to an angel to find a human being insinuating (as many philosophers virtually do) that the universe ought to have been constructed according to his own particular taste! What a comic display of greatness to see the biped stepping out and measuring off the heavens and the earth by the dimensions of his own private encephalon! It is ours to discover what exists, to mingle in nature and be happy. To be dissatisfied with any thing but ignorance and crime indicates a leprous state of mind, unfit for a dwelling-place in creation; but the man who ventures to suggest that things should have been otherwise than they are, is delirious with a fever of ignorance, in which he dreams and dreams, and peoples space with monsters, while the vampire-wings of his sickening spirit cover his eyes from all the beauties of heaven and earth. None suffer so much from the evils of ignorance as those who are most ambitious of excessive knowledge, and it is truly melancholy to see what a maze of mysteries men of pretensions to science often involve themselves in as to the nature of things, losing perception even of the most obvious and important truths, which, like air and water, are common blessings and the inheritance of every peasant.

But what is to be said of moral beauty? Having shewn that the feeling of sensible beauty arises from the *nidus* of the mind, adapting itself to the form of the object named beautiful, it is obviously to be inferred, that when we are under the influence of the feeling of mental beauty not pictorial, our mind itself is imitating, or becoming assimilated, to that mind which is possessed of the beauty we admire. We have seen, however, that in the organic apparatus, the consciousness that we are imitating is disguised from us; and just so, while admiring moral beauty, the fact that we are submitting to an assimilation to that which we admire is disguised also. To explain this, it is necessary to remark, that, when we admire an object of moral beauty, being of a social nature, we wish to become associated with the object admired, rather than be at the particular pains of establishing the admirable qualities in ourselves. Such admiration, seconded by this social desire, constitutes *Love*, all whose promptings are so many guides to a personal imitation, and to the internal possession of the moral qualities beloved; for love invariably prompts to please the object loved; and how are we to please that object but by acquiring those feelings, and doing those actions, which, being observed in the object loved, please us? Thus the institution in our own mind of that which we deem beautiful immediately ensues. The imitation is disguised from us by the interposition of a benevolent feeling, a wish to make the loved object happy; but that circumstance does not take in any degree from the accuracy of the imitation. Thus, by loving, a mind becomes amiable. The moral qualities admired in another, while they seem to continue external during all the time of our admiration, and to be possessed by the object admired alone, are, in reality, by the continuance of our affection, and of the activities to which it leads, germinating in our own breasts, which they are able to fill with blossoms, though the spirit were left to derive all its happiness from its own resources.

This, then, is the sum of the whole matter, and the climax of the mind's action. The love of God who is the inventor of happiness, whose Essence is the treasury of goodness, whose Eye is the fountain of beauty, is the mechanism by which we grow in goodness, and consequently in happiness. And when shall the era come when the stimulus for the mind's activity, according to this constitution of things, shall be over, so that it shall fall into a state of sleep and unconsciousness? Matter imitates form which is a limited and a definite thing, to which any mass, if not prevented, may be perfectly assimilated; and thus the whole material universe may be conceived in time to arrive at a state of stillness and silence, and entire inaction: the imitative tendency towards the perfect form may terminate in universal identity. But the Perfect Mind is infinite, and no created mind, being likened unto him, can ever bring it to pass that there shall be less than an infinite amount of moral beauty remaining to be imitated still. In the ages of eternity a finite mind, dwelling in the presence of God, may receive continual accessions of goodness, and, consequently, of happiness. But the infinite glory of the Divine Nature must always expand in advance of a creature's power to perceive it; and the streams of happiness out of which a blessed spirit can have drunk, reckoning back from any most distant age of eternity to the day of his birth, when his father first smiled on him, and his mother embraced him, must be a number too small to be compared with the fountains which still remain even then with unbroken seals.

A perception of Truth, Conscience, and the Love of God, then, is the trinity, in whose equal presence in the heart the unity of our mental constitution consists. Wherever one or other of these three is weak, or wanting, the mind, though prevented perhaps by the harmonious organization in which it is embodied, from immediately breaking down, is in reality a ruin, and its feelings, when it is left to feel for itself, must only be the experience of the lacerations which it has sustained; for it is obviously contrary to the warrant of nature to assume that the sensibilities of any future state of existence can naturally be different from those which belong to our constitution. It is obviously absurd to imagine that mere wishes on our part can change the eternal laws of the universe, and make the effects of crime to be different from those which are natural. If our constitution be lacerated, the facts of the case demand,—and the whole analogy of nature responds—that some mechanism is required to heal our wounds, and make us fit for our rightful place in creation again.

Thus far science can carry us; but this mechanism, as it must be some supernal application wholly instituted by our Creator, so it can only be learned by revelation.

APPENDIX.

INDEX

OF

ATOMIC WEIGHTS AT THE ZERO OF HEAT.

On inspecting the following table, it may seem to the reader, who has not perused the pages in which these atomic weights are investigated, that, as usual, any number of particles has been fixed on to express the structure of a compound substance, which will best suit the conditions of analysis: but this is not the case; the numbers here given are generally those which are alone fit for constituting symmetrical or neutral compounds of the various elements. Thus it may seem very arbitrary to state, that silica is a compound of four particles of oxygen and five of silicon; but, by consulting the text, it may be learned that these are the only ratios which can give a symmetrical and perfect compound of those two elements, and so in other cases. The atomic structure of very few salts is given, because their crystallizing molecules must be very large, and their investigation has not been minutely attended to in the body of the work. It will be readily perceived by the reader, that the small numeral, with the dot over it, indicates the number of particles expressed by the numerals beneath to which it is attached. The m annexed to some implies that molecules, not particles, are combined; and the + added to the atomic weight in many cases implies that these bodies are subject to have their atomic weights increased by the attachment of accidental atoms.

SINGLE SUBSTANCES.

An atom,	1	Oxygen,	10
Hydrogen,	2	Water,	12
Iron,	4	Boron,	13
Carbon,	5	Fluorine,	15
Calcium,	6	Sodium,	15
Magnesium,	8	Arsenic,	18
Copper,	8	Tellurium,	24
Silicon,	8	Alumina,	24
Phosphorus,	8	Selenium,	26
Sulphur,	10	Manganese,	25
Potassium,	10	Chlorine,	45
Nitrogen,	10	Bromine,	100?

SINGLE AND COMPOUND SUBSTANCES.

An atom,	1
HYDROGEN,	2
Water,	12
A cellular or senate molecule of water,	72
OXYGEN,	10
Vital air, (oxygen 10^{i} + atom 1),	11
Deutoxide of hydrogen, (oxygen 20^{2} + hydrogen 2^{1}),	22
NITROGEN,	10
A binate molecule, (as in air, animals, and nitric acid),	20
Nitric acid, (oxygen 50^{5} + nitrogen 20^{im}),	70
A symmetrical hydro-molecule of nitric acid, (acid 70^{i} + water 60^{5}),	130
Intoxicating gas, (oxygen 10^{i} + nitrogen 20^{2} + atoms 2),	32
Nitrous gas, (oxygen 10^{i} + nitrogen 10^{i}),	20 +
Nitrous acid, (oxygen 20^{2} + nitrogen 10^{i}),	30 +
Hyponitrous acid, (nitrous acid 30^{i} + nitrous gas 20^{1}),	50 +
SULPHUR,	10 +
A quaternate molecule,	40 +
Sulphureous acid, (oxygen 10^{i} + sulphur 10^{i}),	20 +
Oil of vitriol, (water 12^{i} + oxygen 30^{3} + sulphur 20^{2}),	62 +

Anhydrous sulphuric acid,	50 +
Hyposulphuric acid, (oil of vitriol 62^{1} + sulphureous ac. 40^{2}),	102 +
Hyposulphureous acid, Gay-Lussac, (oxygen 10^{1} + sulphur 20^{2}, or their doubles),	30 or 60 +
Hyposulphureous acid, Thomson 1827, (oxygen 10^{1} + sulphur 40^{1m}),	50 +
Sulphuretted hydrogen, (sulphur 40^{1m} + hydrogen 4^{2}),	44 +
Supersulphuretted hydrogen, (sulphur 40^{1m} + hydrogen 2^{1}),	42 +
SELENIUM,	26 +
A quaternate molecule,	104 +
Selenious acid, (oxygen 10^{1} + selenium 26^{1}),	36 +
Selenic acid, (water 12^{1} + oxygen 30^{3} + selenium 52^{2}),	94 +
Selenietted hydrogen, (selenium 104^{1m} + hydrogen 4^{2}),	108 +
ARSENIC,	18 +
A septenate molecule,	126 +
Arsenic acid, (oxygen 10^{1} + arsenic 18^{1}),	28 +
A symmetrical hydro-molecule, (water 12^{1} + acid 140^{5}),	152 +
Arsenious acid, (oxygen 40^{4} + arsenic 126^{1m}),	166 +
Arsenicated hydrogen, one sort, (arsenic 18^{1} + hydrogen 2^{1}),	20 +
———— another sort, (arsenic 18^{1} + hydrogen 6^{3}),	24 +
Orpiment, (arsenic 126^{1m} + sulphur 80^{2m}),	206
Realgar, (sulphur 40^{1m} + arsenic 90^{5}),	130
TELLURIUM,	24
A septenate molecule,	168
Oxide of tellurium, (oxygen 40^{4} + tellurium 168^{1m}),	208
PHOSPHORUS,	8 +
A quaternate molecule,	32 +
Phosphoric acid, (oxygen 10^{1} + phosphorus 8^{1}),	18 +
A hydro-molecule, (water 12^{1} + acid 90^{5}),	102 +
Phosphorous acid, (Dulong ?) water 12^{1} + oxygen 30^{3} + phosphorus 40^{5}),	82 +
Phosphuretted hydrogen, (phosphorus 32^{1m} + hydrogen 4^{2}),	36 +
(For four other sorts, see page 301.)	

BORON,	13
Combining boracic acid, when perfect, (oxygen 30^3 + boron 13^1),	43
Native boracic acid, (two particles of combining acid 86, united by one particle of oxygen 10),	96
A hydro-molecule, (water 12^1 + combining acid 215^5),	227
AMMONIA,	26
A symmetrical hydro-molecule, (water 72^6 + ammon. 26^1),	98
CARBON,	5
Light carburretted hydrogen, (carbon 5^1 + hydrogen 2^1),	7
Olefiant gas, (carbon 10^2 + hydrogen 2^1),	12
&c. &c. &c. &c. &c.	
Fixed air, (carbon 5^1 + oxygen 10^1),	15
Carbonic oxide, (carbon 10^2 + oxygen 10^1),	20
Acetic acid, (carbon 10^2 + oxygen 10^1 + hydrogen 2^1),	22
A hydro-molecule, (water 12^1 + acid 66^3),	72
Citrogen, (carbon 15^3 + oxygen 20^2),	35
Citric acid, (carbon 15^3 + oxygen 20^2 + hydrogen 2^1),	37
Oxalic acid, (carbon 20^4 + oxygen 30^3),	50
Pyragynic acid, (carbon 15^3 + oxygen 40^4),	55
Malic acid, (water 24^2 + olefiant gas 36^3 + carb. acid 90^6),	150
Sugar, (water 24^2 + olefiant gas 36^3 + carb. acid 45^3),	105
Alkohol, (water 24^2 + olefiant gas 36^3),	60
Ether, (water 24^2 + olefiant gas 72^6),	96
Cyanogen, (carbon 15^3 + nitrogen 20^2),	35
Hydrocyanic acid, (carbon 15^3 + nitrogen 20^2 + hydrogen 2^1),	37
(For carbonates of ammonia, and other compounds, see the text.)	
CHLORINE,	45
Aëriform chlorine, (chlorine 45^1 + atoms 5),	50
A symmetrical hydro-molecule, (water 120^{10} + chlor. 45^1),	165
Bromine, (a binate molecule of chlorine 90^1 + atoms 10),	100 ?

Muriatic acid, (chlorine 45^{1} + hydrogen 2^{1}),	47
A symmetrical hydro-molecule, (water 72^{8} + chlorine 45^{1}),	117
Muriate of ammonia, (ammonia 26^{1} + chlorine 45^{1}). (For a crystallizing molecule, see page 382)	
Chloric acid, (chlorine 45^{1} + oxygen 50^{5}),	95
Euchlorine, (chlorine 45^{1} + oxygen 10^{1}),	55
Peroxide of chlorine, (chlorine 45^{1} + oxygen 40^{4}),	85
Sulphurane, (chlorine 45^{1} + sulphur 20^{2}),	65
Phosphorane, (chlorine 45^{1} + phosphorus 16^{2}),	61
Phosphorana, (chlorine 45^{1} + phosphorus 8^{1}),	53
Chloride of selenium, (chlorine 45^{1} + selenium 26^{1}),	71
Chloride of tellurium, (chlorine 45^{1} + tellurium 48^{2}),	93
Chloric ether, (chlorine 45^{1} + olefiant gas 24^{2}),	69
Perchloride of carbon, (chlorine 45^{1} + carbon 5^{1}),	50
Protochloride of carbon, (chlorine 45^{1} + carbon 10^{2}),	55
Chloride of carbon, from Abo, (chlorine 45^{1} + carbon 15^{3}),	60
Chloro-carbonic acid, (chlorine 45^{1} + carbonic oxide 20^{1}),	65
MANGANESE,	35
Peroxide, or black oxide, (manganese 35^{1} + oxygen 20^{2}),	55
Protoxide, or green oxide, (manganese 35^{1} + oxygen 10^{1}), (For other oxides, see the text.)	45
Manganesic acid in combination, (manganese 70^{2} + oxygen 50^{1}),	120
&c. &c. &c. &c. &c.	
SODIUM,	15
Soda, (sodium 30^{2} + oxygen 10^{1}),	40
Common salt, (sodium 30^{2} + chlorine 45^{1}),	75
Sulphate of soda, (sulphuric acid 50^{1} + soda 40^{1}), Glauber's salt, (see page 400).	
Selenite of soda, (selenious acid 72^{2} + soda 40^{1}),	112
Soda of commerce, (carbonic acid 30^{2} + soda 40^{1}),	70
——————— or (pyragynic acid 55 + soda 80),	235
(For these carbonates of soda, see page 401).	

Phosphate of soda, (phosphoric acid 90^{1m} + soda 80^{2} + water 288^{14}).

Another, see page 406, (phosphoric acid 36^{2} + soda 40^{1} + water 198^{11}).

Borax, (Klaproth), see page 404, (boracic acid 218^{1m} + soda 80^{2} + water 204^{11}).

Arseniate of soda, see page 404, (arsenic acid 140^{1m} + soda 40^{1}).

Acetate of soda, (acetic acid 66^{1} + soda 40^{1} + water 72^{4}), 178

(For the probable structure of complicated salts, see the text.)

POTASSIUM, ... 10

Potassa, (potassium 50^{5} + oxygen 10^{1}), ... 60

Chloride of potassium, (chlorine 45^{1} + potassium 50^{5}), . 95

Nitre, (potassa 60^{1} + nitric acid 70^{1}), . . . 130

Chlorate of potassa, (potassa 60^{1} + chloric acid 95^{1}), . 155

Cream of tartar, (potassa 60^{1} + tartaric acid 164^{1}), . 234

Manganate of potassa, (potassa 60^{1} + manganesic acid 120^{1} + water 48^{4}).

(For sulphates, carbonates, and oxalates, see text).

MAGNESIUM, ... 8

Magnesia, (magnesium 16^{2} + oxygen 10^{1}), . . 26

Epsom salt, (magnesia 52^{2} + oil of vit. 124^{2} + water 144^{12}).

Muriate of magnesia, &c. see page 422.

CALCIUM, ... 6

Lime, (calcium 30^{5} + oxygen 10^{1}), ... 40

Chloride and muriate of lime, (a molecule composed of five of muriate lime round one of lime, see page 425).

Carbonate of lime, (lime 40^{1} + carbonic acid 30^{1}), . 70

(For sulphate, nitrate, phosphate, borate, arseniate, oxalate, &c. see page 428, *et seq.*)

SILICON, ... 8

Silica, (silicon 40^{5} + oxygen 40^{4}), ... 80

Nascent silica, (silica 8^1 + oxygen 10^1),	18
Hydrates of silica—	
Menilite, (water 12^1 + silica 80^1).	
Hyalite, (water 12^1 + silica 160^2).	
Common opal, (water 12^1 + silica 240^3).	
Precious opal, (water 36^3 + silica 320^4).	
Okenite, (silica 80^1 + lime 40^1 + water 24^2).	
Table spar, (nascent silica 90^5 + lime 80^2).	
&c. &c. &c. &c. &c.	
THE FLUORIC PRINCIPLE,	15
A hydro-molecule, (water 12^1 + fluorine 30^2),	42
Fluor spar, (fluoric 15^1 + lime 40^1),	55
Cryolite, topaz, &c., see page 442.	
Fluo-silicic and fluo-boric acid gas, see page 443, &c.	
ALUMINA,	24
Alum, half a molecule, (sulphuric acid 200^4 + alumina 72^3 + potassa 60^1 + water 276^{23}).	
Phosphate of alumina, (acid 90^5 + alumina 95^4 + water 72^6).	
Acetate of alumina, (water 12^2 + acid 66^3 + alumina 24^1).	
Aluminous minerals—	
Petrosilex, from Sahlberg, (alumina 24^1 + silica 160^2).	
Felspar, (alumina 96^4 + silica 320^4 + potassa 60^1).	
Albite, (alumina 96^4 + silica 320^4 + soda 40^1).	
Analcime, (alumina 72^3 + silica 240^3 + soda 40^1).	
&c. &c. &c. &c. &c.	
COPPER,	8
A quinate molecule,	40
Peroxide, (copper 40^5 + oxygen 10^1),	50
Protoxide, (copper 80^{10} + oxygen 10^1),	90
Vitreous copper, (sulphur 10^1 + copper $40^{1\,m}$),	50
Chloride of copper, (chlorine 45^1 + copper 80^{10}),	125
Malachite, Vauquelin, (oxide of copper 50^1 + carb. acid 15^1),	65

(For phosphate of copper and arseniates, see page 460).

Blue vitriol, a semi-molecule, (oxide of copper 50^1 + oil of vitriol 62^1 + water $42^{3\frac{1}{2}}$).

Nitrate of copper, (nitric acid 70^1 + oxide of copper 50^1).

Verdigris—

Trisacetate of copper, (acetic acid 22^1 + peroxide 50^1).

Subsesquacetate, (acetic acid, 44^2 + peroxide 50^1).

Acetate, (acetic acid 66^3 + peroxide 50^1).

(For water, and the molecular structure of such salts, see page 462).

IRON, ...	4
Ternate molecule, ...	12
Denate molecule, ...	40
Red oxide, or peroxide, (iron 24^{2m} + oxygen 10^1), .	34
Hæmatite, (water 12 + peroxide 102^3), . .	114
Ochre, (water 12^1 + peroxide 34^1), . . .	46
A symmetrical molecule, (water 72^6 + peroxide 204^6),	276
Black oxide, or protoxide, (iron 40^{1m} + oxygen 10^1),	50
(For other oxides, see page 473).	
Iron-pyrites, (sulphur 40^{1m} + iron 36^{3m}), . . .	76
Ferrane, (chlorine 45^1 + iron 40^{1m}), ...	85
Ferranca, (chlorine 45^1 + iron 24^{2m}), . . .	69
Carbonate of iron, (protoxide 50^1 + carbonic acid 30^2),	80
Bergmann's artificial carbonate, (protoxide 50^1 + carb. acid 15^1),	65
Natural phosphate of iron, (protoxide 50^1 + acid 36^2), .	86
(For the structure of various sulphates, see page 478).	
Ferro-cyanic acid, (cyanogen 30^1 + iron 20^5 + hydrogen 2^2),	52
Prussian blue, (acid 52^1 + peroxide 34^1 + water 12^1), .	98

PLATE I.

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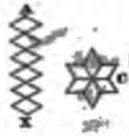

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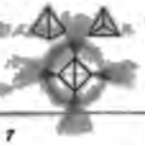

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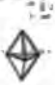

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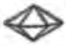

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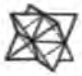

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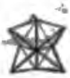

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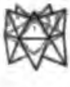

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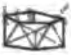

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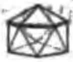

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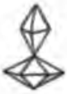

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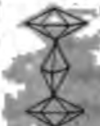

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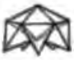

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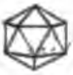

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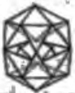

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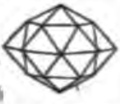

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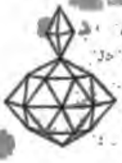

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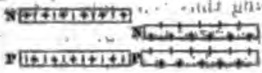

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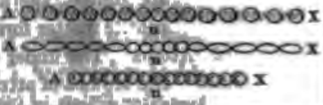

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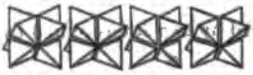

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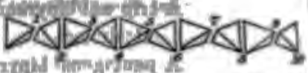
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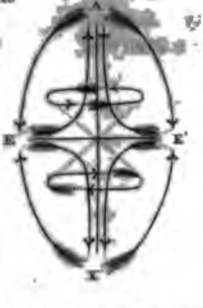

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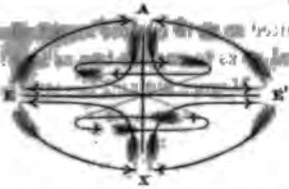

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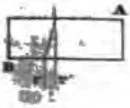

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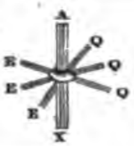

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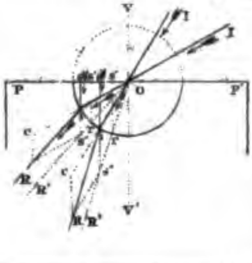
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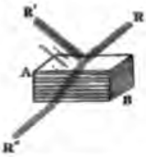

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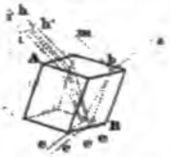
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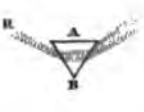

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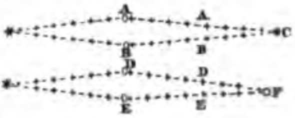
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EXPLANATION OF FIGURES.

PLATE I.

Fig. 1. A X. a flexible polarized axis, positive and negative at its opposite extremities. C, the same, in which the consecutive poles are united, the axis being thus bent into a circle, and the subtile matter formerly polarized now circulated. See p. 12.

2. Atoms. The under one invested by its sphere of subtile matter, the regions of attraction being represented by the four pencils crowning the angles.

3. A trigonal bipyramid formed by two atoms united by their bases. Hydrogen.

4. A pentagonal bipyramid formed by five atoms united by an edge. Carbon.

5. Eight atoms united so as to enclose an octaedral cavity. Silicon.

6. Six atoms united so as to enclose two as in Fig. 3. or a cavity of the same form. Magnesium and Calcium.

7. Ten atoms united so as to enclose five as in Fig. 4. or a cavity of the same form. Sodium and Potassium.

8. Five triangular bipyramids (Fig. 3.) touching by an equatorial angle, and bent down so that the polar angles of one cohere to the equatorial angles of another, a form destitute of an axis. Oxygen.

9. An electro-positive form Fig. 4. united to a conformable electro-negative form, Fig. 8. A particle of Carbonic Acid.

10. Two substances, Figs. 3 and 4 united, which, though both electro-positive in relation to Fig. 8., are not equally so, and are therefore positive and negative in relation to each other, and capable of union. Light carburetted Hydrogen.

11. The same elements as in Fig. 10. united, so as to form a symmetrical particle. Olefiant gas.

12. Five triangular bipyramids (Fig. 3.) united by an edge. A combining particle of Nitrogen.

13. Two of Fig. 12. united so as to produce a symmetrical solid particle. Animal nitrogen.

Fig. 14. The same as Fig. 13., the two particles adhering only by five equatorial angles. Atmospherical nitrogen.

15. The same as Fig 14. with the five equatorial cavities filled with five of Fig. 4. to which they are conformable. Chlorine.

17. A substance resulting from the union of Figs. 3 and 15, which are positive and negative in reference to each other Muriatic acid.

16. Polarity developed by induction.

18. Figures illustrating the expansion and contraction of a fibre composed of spheroidal molecules in consequence of a change in the polarity of the particles.

19. An electro-negative molecule, }
20. An electro-positive molecule, } See page 38.

22. A fragment of a perfect ray of the radiant medium (the atoms being represented almost contiguous, in order to shew their relationship), or a ray of common light.

24. A fragment of a singled or polarized ray, Fig. 22 consisting of four such in transverse positions two and two.

25. Illustration of the phenomena of interference, see page 91.

26. An axis, prism or ray of light, singled or polarized by reflection from a reflecting cone, by which an equator of light is developed polarized in a plane transverse to that of the axis, so far as its light is polarized.

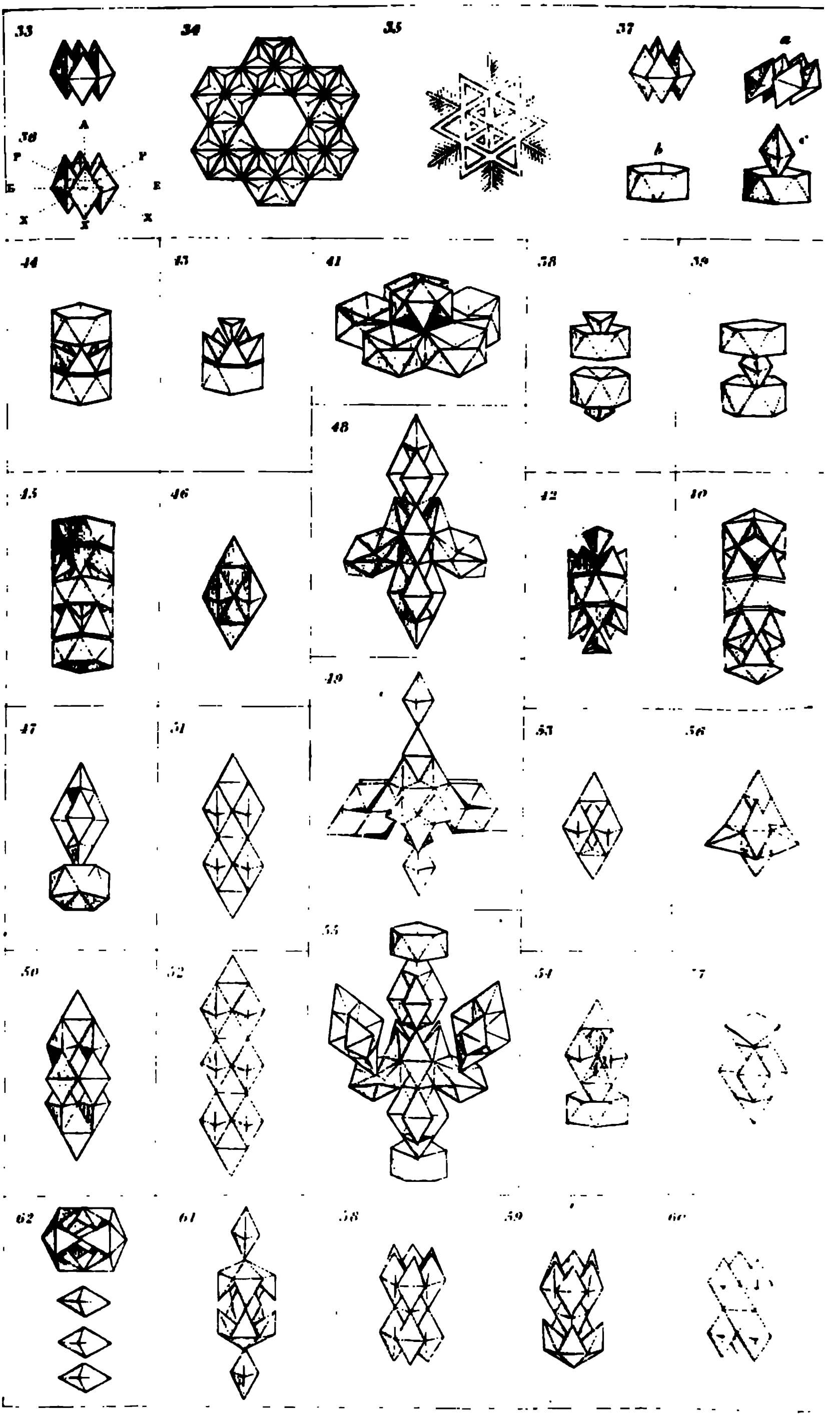
27. A diagram illustrating the cause of the constant ratio of the sines in refraction.

28. A photomotive pile or pile of glass plates, for polarizing light.

29. One ray of common light parted into seven by one rhomboid of Iceland crystal, copied from Malus.

30. The symmetry of common or perfect light destroyed by refraction through a prism.

PLATE II.


a
A
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E
X
X
X
b
c

PLATE II.

Fig. 33. A particle of water constituted of six particles Fig. 3. symmetrically united.

34. A senate or cellular molecule of water—35. A flake of snow of a most perfect sort, copied from Scoresby—36. A particle of water with the directions of the axes of polarization marked by dotted lines—37. *a b c* figures illustrative of the decomposition of water.

38. Two particles of vital air forming one symmetrical molecule.

39. A particle of deutoxide of hydrogen.

40. A particle of nascent atmospherical air composed of a particle of oxygen, Fig. 8. with one of nitrogen, Fig 14. in each pole.

41. A particle of nitric acid.

42. A particle of intoxicating gas.

43. A particle of nitrous gas.

44. A particle of nitrous acid.

45. A particle of hyponitrous acid, composed of one of nitrous gas, Fig. 43. combined with one of nitrous acid, Fig. 44.

46. A particle of sulphur.

47. A particle of sulphureous acid.

48. A particle of oil of vitriol.

49. A particle of sulphuretted hydrogen composed of a quaternate molecule of sulphur, with a particle of hydrogen on each pole.

52. A particle of selenium.

51. A particle of arsenic.

50. A particle of tellurium.

53. A particle of phosphorus.

54. A particle of phosphoric acid—55. A molecule of glacial phosphoric acid, composed of a nucleus of water, with three particles of acid, one on each alternate segment of the equator, and one in each pole.

56. The lightest sort of phosphuretted hydrogen, (Davy's Elements).

57. A particle of boron.

58. A particle of ammonia—59. Ammonia made conformable to potassium Fig. 7, by the loss of a particle of hydrogen—60. Ammonium—61. Nascent ammonia—62. Ammonia destroyed by electricity.

PLATE III.

Fig. 63. A ternate molecule of carbon Fig. [illegible]—Fig. 64. A quinate molecule as involved in Fig. 14.—Fig. 65. A septenate molecule—Fig. 66. a duodenate molecule or a molecule of diamond—Fig. 67. A spiral molecule of carbon.

68. A symmetrical molecule of carbonic acid composed of two particles of Fig. 8.

69. A particle of carbonic oxide.

70. A particle of dry acetic acid, three of which on the alternate segments of a particle of water constitute a hydro-molecule of acid, such as is commonly found.

71. A particle of citric acid.

72. A particle of oxalic acid.

73. A particle of which three on the alternate segments of a binate molecule of water, constitute a particle of malic acid.

74. A particle of which three on the alternate segments of a binate molecule of water, constitute a particle of sugar.

75. A particle of alcohol. It also represents sugar supposing three of carbonic acid added on the three poles of the three carbons towards either extremity. When all the carbons are covered with carbonic acid, that is, when the other three poles are covered also, the form becomes malic acid.

76. A particle of ether, or alcohol with the quantity of olefiant gas doubled, every segment of the water instead of every alternate segment being covered.

77. A particle of hydrocyanic acid.

78. A particle of the black oxide of manganese, composed of a particle of Fig. 65., with one of Fig. 8. on each pole.

79. A particle of soda composed of one of oxygen, Fig. 8. in the centre, with one of sodium, Fig. 7., (the solid form), on its opposite sides.

80. A particle of common salt, composed of one of chlorine, Fig. 15., with one of soda, Fig, 7., (the solid form), on each pole.

81. A particle of potassa composed of one of oxygen, Fig. 8. in the centre, with five of potassium, Fig. 7., (the hollow form), symmetrically around it.

82. A particle of magnesia having a structure analogous to soda, magnesium Fig. 6. (the solid form) occupying the place of sodium Fig. 7. (the solid form.)

83. A particle of lime having a structure analogous to potassa, calcium Fig. 6., (the hollow form) occupying the place of potassium Fig. 7. (the hollow form.)

PLATE III.

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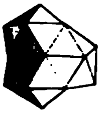

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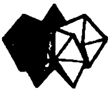

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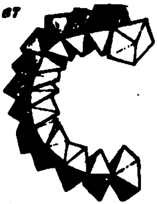

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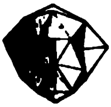

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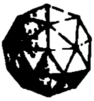

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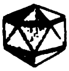

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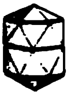

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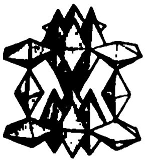

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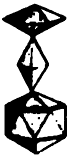

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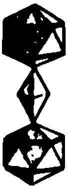

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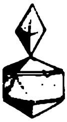

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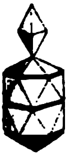

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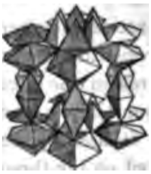

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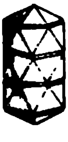

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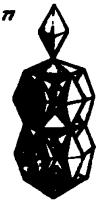

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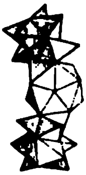

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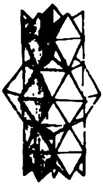

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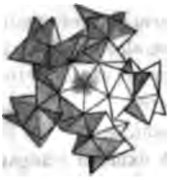

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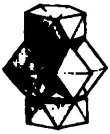

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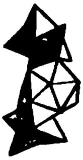

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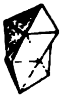

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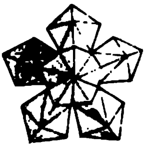

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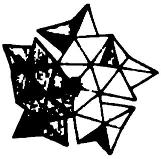

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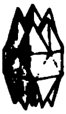

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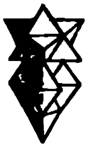

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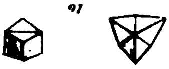

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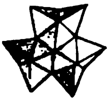

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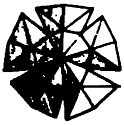

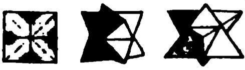

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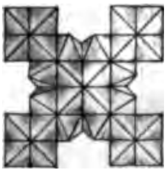

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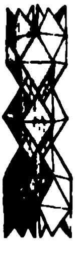

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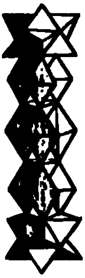

Engd by W.H. Lizars.

Fig. 84. Three particles of silicon in different projections in the first line. Beneath is one of silica, composed of one of silicon in the centre, then four of oxygen, one on each aspect of the central silicon, and then four more of silicon, one to each particle of oxygen.

85. A particle of the fluoric principle. Fig. 86., two such inserted into the poles of a particle of water.

87. A particle of alumina. Fig. 88., two such inserted by a particle of water, (these figures are inaccurately drawn).

89. A particle of copper. Fig. 90. a quinate molecule of the same.

91. Particles of iron in different projections. Fig. 92. a ternate molecule. Fig. 93. the half of a deuate molecule.

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